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## *THE ADMISSION EXAMINATION IN ENGLISH.*

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ABOUT ten years ago all, or nearly all, the New England colleges agreed to model their admission examinations in English after a fixed type. At each college the examination was to consist of two parts — the writing of a short composition on a subject taken from one of a given list of books, and the correction of certain specimens of bad English. For several years the Massachusetts Institute of Technology has been following, to some degree, the plan adopted by these colleges. In the catalogue for this year, indeed, it so phrases the requirements for admission in English that they actually coincide in all essential particulars with those prescribed for entrance into the best New England colleges. "The candidate will be required to write," says the catalogue, "a short English composition — correct in spelling, punctuation, grammar, idiom, and division into paragraphs, and plain and natural in style — on some subject already familiar to him. He will be judged by how well he writes, not by how much he writes. For convenience, and in order that the candidate may be acquainted with good models of style, the subjects will be taken from one or more" of certain standard books, with all of which the applicant is expected to be familiar. "The candidate will also be required to correct specimens of bad English set for him at the time of the examination."[1]

[1] See Professor L. B. R. Briggs's article on the Harvard Admission Examination, in *The Academy* (Syracuse, N. Y.) for September, 1888, and Professor A. S. Hill's chapter on English in the Schools, in "Our English" (Harper & Brothers, 1889). Strang's "Errors in English Accidence" (D. C. Heath & Co., 1888) and David Salmon's "Senior School Composition" (Longmans, Green & Co., 1891) indicate the kinds of books best suited for preparatory school work.

Now that the Institute has virtually accepted the same standards and the same requirements that are in vogue in the best New England colleges, we should do well to see clearly what principles underlie these requirements. Briefly, these principles, it seems to me, are two: first, that a boy of sixteen or seventeen, properly fitted for college or for a technical school, should be able to write correctly and with some ease on subjects which he already knows; second, that he should know what is right and what is wrong in matters of grammar, syntax, and the like, about which there can be no possible doubt. These two principles, it will be noticed, are respectively the bases of the two parts of the admission examination.

1. The first point is one which our preparatory schools sometimes wilfully, sometimes carelessly, neglect. Were it possible, most teachers of English would, I think, prefer that there should be no special admission examination in English, and that the candidate should be judged by the English of all his examination papers, not by the English of a single paper. Such a system is not at present practicable at any school or college which I know; but we should bear in mind that the object of this part of our examination in English is not to satisfy ourselves that the candidate possesses a given amount of information, but simply to make sure that he is sufficiently fluent and correct in expression to enable him to carry on his work in other branches, as well as in English, with profit to himself and without hindering others. For in college and in technical school alike the general complaint of the various departments of study is that many students are unable to express themselves satisfactorily. Such students come to us spelling badly, without any proper sense of English idiom, writing awkwardly and with great effort. They are obviously, in short, as unfitted for many parts of their college or professional training as they are for that written communication with private individuals or public bodies which, to a greater or less degree, must form a constant part of every man's professional or private life. Such men, then, come to us heavily handicapped in our common struggle for expression; and it is to the preparatory schools that we look for such methods and results of teaching as shall reduce to a minimum this percentage — already too large — of students who may perhaps be able to think, but have no adequate means of showing us by written words that they think or what they think.

As a matter of fact, the bulk of our preparatory schools are doing

nothing of the kind. In the classics, in modern languages, in history, in mathematics, in physics, there is, I understand, a marked endeavor on the part of preparatory schools to train the candidates for colleges and technical schools by methods which the higher institutions themselves approve. In English alone the fit which the preparatory schools give is too often not a "fit" at all, but a mere guess at the easiest way to fulfill the letter, and not the spirit, of the requirements. This state of things, it seems to me, is due to a general failure on the part both of preparatory schools and colleges to agree on the position which the study of English composition rightfully takes in all our work, elementary or advanced. In the sense which I take it, the study of English composition is, and must be, rather a serving-maid than a mistress, rather a means than an end. Rhetoric is nothing more nor less than the art or power of expressing plainly, clearly, and adequately, the thing which you most want to express. It is an art, then, which any boy of good sense can almost learn for himself — in fact, does usually learn for himself, if he learns it at all. The function of the instructor in English composition in a preparatory school, as well as in the college, is merely that of helping a boy, systematically and with a proper modicum of theory, to a boy's natural birthright — that of being able to say what he wants to say, or to write what he wants to write.

There are several obvious faults which a diligent reading of examination books shows in the early training in English of candidates for admission to colleges and technical schools. The first fault is that the boy has been taught to write as well as he could only when he wrote for his English master. To the ordinary schoolboy English composition is too much a matter of a fixed hour and a fixed place, and not a matter of everywhere and always. He hands in his composition on Friday, gets it back again on Wednesday, and neither in the interim thinks anything further about trying to write well, nor afterwards applies on other occasions what help he might have received from that particular exercise. But English composition — the art or power of making another man understand what you mean through written words — is not an isolated act, like attendance at a yearly convention, but a habit, a constant series of acts. If we teach a boy to write well — that is, to express what he has to say briefly, clearly, and accurately — we must teach him to

write well not only on the rarer occasions of fortnightly themes, but on all occasions — in his examination papers, in the note-books of the physical or chemical laboratory, in translating into English from other languages, in mathematical demonstrations, in absolutely all the work which he does. Good writing is good thinking, good thinking out into language, and applies as well to work done under the teacher of physics as to that done under the teacher of English.

A second fault which I notice in the English preparation of subfreshmen, as I believe they are technically called, is that they have usually been trained to write on too large subjects. A boy writes best about things which he knows about. But "Hope," "Fortune," "Youth's Best Lesson — Obedience," "The Proverbs of the World" — these, I submit, are usually subjects out of the reach of boys fitting for college. The following titles, on the contrary, taken absolutely at random from a bundle of freshman themes, will indicate that in the majority of cases the writer had chosen a subject in which he was really interested, about which he really knew something, and on which he was likely to write with success. These are the titles: "Boston Winds in December," "The Blue Jay," "The Advantages of a College Education," "Sunday Morning," "The Alternating Current Dynamo," "A Moral Meeting," "The Mechanics' Fair," "Some Facts about the Telephone," "A Ride on a Raft," "A Blockade," "Safety Bicycles," "A Fishing Trip."

A third fault, somewhat less important than those I have mentioned, but perhaps nearly akin to them, is that a boy is often set to writing about books before he is ready to be of his own accord interested in them. Such a practice only confirms the pupil in what is too often his instinctive belief, that composition is merely a scholastic exercise, only applicable to books, and with no relation to the half-dozen kinds of writing which every boy practices in his daily life. To be sure, the subjects given the candidate at the time of the examination are taken from certain well-known books in English literature, the list of which is published in the catalogue of the institution. We choose such subjects because it is the uniform practice of New England colleges to require a knowledge of these books for admission, and because a teacher preparing boys for both colleges and the Institute of Technology should not be forced to divide his class into two squads, as if there were an appreciable difference between the amount or kind of drill in English needed

for the Institute, and that needed for Harvard or any other reputable American college. We choose them, too, because it is the easiest way of providing subjects with which a candidate can make himself familiar, and because the reading of good books brings obvious advantages. But, after all, the examination is one not in literature, but in expression, and in preparing for it care should be taken not to make the pupil write in the conventional school composition style about books, and, if possible, not to write about them at all until they begin really to interest him. He should be taught to have his own ideas (not necessarily those of his teacher) about what he reads, and to be used to writing them down. The more simply he writes, the less artificiality of thought he acquires, the greater the advantage in power of expression is likely to be.

The only other prominent fault which I have noticed is a strong tendency in candidates, sometimes in the best candidates, to write not as boys should, but in a fashion more appropriate to Johnson, Macaulay, or the *Edinburgh Review*. This bookish trait, which it is one of the first duties of a college instructor to eradicate, is illustrated by the following exact transcript of an essay written at an admission examination:

"My course in English for the last four years has been carried on in the X—— school building at Y——. This course was *admirably arranged* by Madame Z——, *a woman of great literary ability and a keen perception of what is lacking and of what is necessary for the superficial scholar of this day*. In this course the writing of composition is the most prominent feature. At the end of each term during the year a 'long' composition is given (subject stated) to the student to write, while every second week throughout the year an abstract is written in the class from memory. The subject of this abstract is taken from *some great literary production, the substance of which is committed to memory, and rewritten in an abridged form after the style of the author*. The character of this drill is very simple at first becoming harder each succeeding year; when at the end of the course, one finds out that he is not only well informed on a good many subjects, but through the constant practice of abstract writing he expresses himself with much readiness and facility and *through the medium of the long composition he has become capable of deep thought and analysis of large subjects*.

"Important as composition writing is, time is found for the pursuit of other subjects. I am compelled to read and be questioned on the standard English poets, essayists, criticts and novelists, with particular attention to their style. Accompanying this work we must commit to memory fragments of the productions so we take them up in turn, and have some practice in the analysis of these subjects without expanding them.

"Accompanying but not directly connected, with the study of Literature is a very elementary course in philology. On one day out of the week I am compelled to look up the history of ten words in Skeats dictionary, with a few Aryan and Teutonic roots to memorize.

"Should this course seem a little desultory, or too comprehensive for an ordinary High school, it must be understood that five hours a week are given to it, and that by far the greater part of the work is done outside of school at the students will.

"*With respect to my direct preparation for this examination I have resorted to home studying and reading.* I have kept up a constant course of reading for the last year; principally with the standard novelists. But in many cases I conflict with my school course where I am compelled to sacrafice my private reading. *It is unnecessary to say that I have resorted to a book on Literature for a more complete preparation of the standard books and authors* which we would not be likely to obtain in a small *home* library."

The sentences which I have italicized will perhaps indicate most plainly the real difficulty. Almost every line shows the traces of the method in which the writer has been drilled. The style which he had been forced to cultivate was not one which he could slowly work out for himself, and which should always be natural. "The subject of his [this] abstract is taken from some great literary production, the substance of which is committed to memory, and rewritten in an abridged form after the *style* of the author."

2. The principle which underlies the other part of our examination — that of correcting specimens of bad English — is a simple one. Here we test not expression, but knowledge. Rhetoric really consists of questions of taste and questions of absolute right and wrong. Drill in matters of taste we can afford to leave, for the most part, until the student is a freshman in college. There he can best attain skill in the exact choice of words with all their fine shades of meaning, in deftly framing them into well-balanced sentences, in coherent logical structure both of paragraphs and of the larger units of composition, in all that sound and nice thinking out into language which makes a man write clearly, forcibly, and pleasantly. But there is much in writing which is not a matter of taste, but of knowledge. And that knowledge a candidate should have when he presents himself for the admission examination. He should spell correctly, he should be familiar with the main principles of punctuation, he should know the difference between *shall* and *will* and *lie* and *lay*, and, in general, he should be exactly informed about plain questions of syntax and idiom about which there can be no doubt. That an average candidate does not have this exact knowledge the reader will find by examining the following random extracts from the essays written at an admission examination:

"On the shoar of the Arcadian land, the small village of Grand-Pré was siduated: . . . here, too, her farther lived and worked on his fertil farm; at peace with his neighbors, with all the world."

"In preparing for the Institute this fall, I was only studying my 'conditions,' of two years ago, when I was told I would have to take all of the examinations over, and the result will be, that I will be 'conditioned' in six, and perhaps seven studies."

"In the grave yard in Philadelphia, there lies to nameless graves side by side."

If boys will write in this fashion, the examiner must find some means of testing their knowledge point-blank. This he does by printing a dozen or so sentences, in each of which there are palpable errors, and asking the candidate to correct them. If he cannot detect common blunders when they are so isolated as to provoke discovery, it is not likely that he will be successful in expelling the same errors when they occur — *currente calamo* — in his own composition.

Such are the principles, as I understand them, which underlie the requirements in English for admission to the New England colleges and to the Massachusetts Institute of Technology. For the advantage both of the college and the preparatory school these requirements should be as definite as possible. In almost all other subjects it is well understood where a student's preparation should begin and where it should end. It is only when the requirements in English shall likewise be definitely understood that the teaching of English in colleges or in schools can have the best, or even good, results.

# THE SPECIFIC ORGANISM OF TYPHOID FEVER

## (*BACILLUS TYPHOSUS—EBERTH*).

By GEORGE W. FULLER, S.B.

Since the recognition of the germ theory of disease, typhoid fever is generally attributed to the presence of a definite organism, namely, the typhoid fever bacillus. This organism exists sometimes in air, milk, soil, and water, and consequently is highly interesting to the sanitarian. With the occurrence, from time to time, of typhoid fever epidemics, the need and importance of its study is felt, particularly by those in charge of water supplies. The different phases presented in these epidemics render this study of interest not only to the bacteriologist but to the sanitary engineer and the sanitary chemist.

At the suggestion of Professor Sedgwick, I propose to record the principal literature upon the typhoid fever bacillus, citing its history and specific characteristics.

### History.

The infectious nature of typhoid fever was recognized long before the dawn of bacterial science and the discovery by Eberth of the specific germ. The studies of the progress of epidemics, by Galen, Huxam, Pringle, and Frank, showed danger in putrefying animal matters, and gave rise to the expression, *the source of contagion.* Budd[1] and Murchison[2] proved that the cause of typhoid fever sometimes existed in air, and particularly in potable waters contaminated by fæcal matter or the products of putrefaction. To Murchison, with his pythogenic theory already in existence, the presence of putrefying matter seemed sufficient; but not to Budd, who concluded "that typhoid fever is in its essence a contagious or self-propagating fever; and that the living body of the infected

[1] Typhoid Fever; its Nature, Mode of Spreading, and Prevention, London, 1873.
[2] Treatise on the Continued Fevers of Great Britain, London, 1862.

man is the soil in which the specific poison, which causes the fever, breeds and multiplies. Reproduction of this poison in the infected body, and the disturbance attaching to it, constitute the fever." This great observer was, accordingly, an early exponent of the germ theory of disease, and rigid bacteriological researches in subsequent years have confirmed his theory.

In 1864 Tigri announced to the Academy of Sciences that he had found numerous bacteria in the pulmonary veins, and particularly in the left heart of a man dead of typhoid fever. His observations were confirmed by Mégnin[1] two years later.

Coze and Feltz,[2] in 1866, in their work on infectious diseases, described bacilli which they found in blood. They were $2-5\,\mu$ (one thousandth of a millimeter) long, segmented, slightly motile, and morphologically resembled the *bacterium catenule* of Dujardin. Hallier,[3] in 1868, described as typhoid germs two micrococci of different size.

In studying a complicated case of typhoid fever and of miliary abscess of the kidney, Recklinghausen[4] found some microörganisms to which he laid no claim as to pathogenic value, but of which he remarked that, if there was an active principle of typhoid fever in existence, it could be found in other parts than the blood. Modern science has shown that he simply found some microörganisms of suppuration, introduced by secondary infection.

Eberth,[5] in 1873, in his first work on typhoid fever, endeavored to reconcile these varying opinions. He found microörganisms only in internal ulcerations on the point of healing or of mortification. The organisms described in the blood or internal organs of typhoid fever victims he considered to be introduced secondarily into the system.

In 1875 an English writer, Klein,[6] described some organisms found in the intestines, mesenteric glands, and fæces of typhoid fever victims, as micrococci, varying in size from that of a fine granule to double that of a blood globule. Isolated, or in pairs, says the author, they have in general the configuration of a sphere, of a sand grain,

[1] Comptes rendus, Académie des Sciences, Paris, 1866.
[2] Gazette Médicale de Strassbourg, 1866.
[3] Virchow's Archiv, 1868.
[4] Verhandlungen der medicinischen Gesellschaft, Wurtsburg, 1871.
[5] Zur Kenntniss der bacterischen Mykosen, Leipzig, 1873.
[6] Reports of Medical Officers, London, 1875.

or of a bean. This article brought the writer great renown in England. To-day the micrococci of Klein are classified among the ordinary and numerous species of micrococci which inhabit the intestines.

Browicz,[1] Sokoloff,[2] and Fischl[3] described as typhoid bacteria some oval micrococci found in the kidneys, spleen, and intestines of typhoid fever victims. They were only organisms of putrefaction, however. These works were all futile, abounding in contradictory definitions; the typhoid organism was yet to be found.

Eberth, in a series of articles published in 1880 and 1881, in Virchow's Archiv, first described the organism which now bears his name. Whether it was identical with the one previously described by him in 1872, it is impossible to say, as in former work his description was insufficient to characterize it. But with the introduction of aniline colors into bacteriological technique, he was able to note some of its morphological characteristics. He found the organism, which is now generally considered to be the pathogenic agent of typhoid fever, in the mesenteric glands and spleen of typhoid fever victims, but never encountered it in the blood or organs of persons affected with other diseases. It is a bacillus, says Eberth, rounded at the ends, elongated, sometimes oval, containing sometimes in its interior small dull bodies resembling spores, one to three in each bacillus; takes the aniline colors very badly, and occurs in sections in masses of varying number. This now appears to have been a great discovery. Although he merely described some of the morphological characteristics, yet the bacillus could be differentiated, in a certain measure, from other organisms.

In the same year, 1881, Klebs[4] confirmed the discovery of Eberth, but found, moreover, some elongated filaments in nearly all the organs of typhoid fever victims. These he considered to be bacilli of Eberth in a more advanced stage. Eberth's investigations were again confirmed by Koch,[5] who condemned the work of Klebs, considering the filaments foreign to the disease. Confirmation was

[1] Comptes rendus, Académie de Cracovie, 1875.
[2] Virchow's Archiv, 1876.
[3] Prager medicinische Wochenschrift, 1878.
[4] Archiv für experimentelle Pathologie, 1881.
[5] Mittheilungen aus dem Kaiserlichen Gesundheitsamtes, Bd. I.

also given by Mayer and Friedlander[1] in Germany, and by Coates[2] and Crookes[3] in England.

Morphological characteristics alone, however, are not sufficient for classification. The bacteriological methods at this time were crude, and known to very few investigators. But a great step was soon taken in bacteriological progress, namely, the invention by Koch of the solid gelatine peptone culture medium now in general use. By its means Gaffky[4] was able to obtain a pure culture of typhoid bacilli, to study their growth, spore formation, and other morphological characteristics leading to classification. The work of Gaffky was confirmed in France by Cornil.[5]

The methods for the differentiation of the typhoid bacillus were now fairly well established. In 1886 the infection of the lower animals by this organism was carefully studied, as will be shown later in detail.

## Specific Characteristics.

Morphology.— The typhoid organisms, when examined in a hanging drop under the microscope, are seen to be bacilli, two to three times as long as broad, possessing an energetic movement. For detailed study, staining is necessary. The typhoid bacillus, unfortunately, is stained with some difficulty. This is probably due to the ease with which it is decolorized in the necessary processes of preparation. It is best stained by Ziehl's[6] and Loeffler's[7] solutions. A thin film of bacilli is placed on a cover slip by the aid of a sterilized platinum needle, dried in the air and passed three times through the flame of a Bunsen lamp. The coloring agent is now added for a few minutes. Great care is necessary in removing the excess of coloring agent; otherwise the bacilli will be faintly or not at all stained. The excess is best removed by filter paper or by a fine stream of water directed from a wash bottle upon the edge

[1] Untersuchung über den Bacillus des Typhus abdominalis, Berlin, 1881.
[2] British Medical Journal, March 25, 1882.
[3] *Ibid.*, July 1, 1882.
[4] Mittheilungen aus dem Kaiserlichen Gesundheitsamtes, Bd. II, pp. 372–403.
[5] Journal des Connaissances Médicales, 1884.
[6] 100 grms. distilled water,
5 " carbolic acid (crystals),
10 " alcohol,
1 grm. fuchsine.
[7] 30 cc. conc. alcoholic solution of methylene blue,
100 cc. of 0.01% KOH solution.

of the cover slip. The preparation is then dried and mounted in balsam.

Upon examination the bacillus generally appears $1-3\ \mu$ long, $0.4-0.7\ \mu$ in diameter, and rounded at the ends. Its size is not constant. No organism, says Gasser,[1] is so polymorphous as the typhoid bacillus, even when it is grown in the same culture medium. It not only appears to be a bacillus of very varying dimensions, but has been observed by Litzerich[2] to resemble a micrococcus. From old cultures grown in bouillon or sterilized milk it measures $5-8\ \mu$ in length and $2-3\ \mu$ in diameter. Vaillard and Vincent[3] grew the typhoid bacillus on human spleen bouillon, and found it to measure $120\ \mu$ in length. The possible objection, that it was not a pure culture of the typhoid bacillus, was removed by the fact that the bacillus easily resumed its normal size and characteristics when transferred to agar.

Examination frequently shows also a round or oval space in the center of the bacillus which is not stained. This was noted by Eberth,[4] Mayer and Friedlander,[4] Artaud, and was first carefully studied by Gaffky.[4] Artaud[5] found this to be a constant characteristic in preparations taken from organs of typhoid fever victims; and without studying it when grown on the different culture media, with which he was but little familiar, hastily concluded that this was a means of differential diagnosis from other bacilli. Gaffky's researches on its growth on gelatine showed it to almost constantly possess the cylindrical form. On potato, however, it gave the "shuttle" appearance.

Several reasons have been advanced in explanation of this non-stained space in the center. Artaud considered it due to the presence of a central spore, and claimed to have seen one or two small spores within the space. Other writers have suggested that the stained ends were spores. Chantemesse and Widal[6] attributed it to the partial degeneration of the center of the bacillus. In multiplication the bacillus divides at this point. In support of their theory, they have been able to produce this result artificially, by the growth

[1] Archives de Médecine Expérimentale, January, 1891.
[2] Archiv für experimentelle Pathologie, Bd. IX, p. 312.
[3] Referred to by Gasser, *loc cit.*
[4] *Loc. cit.*
[5] Étude sur l'étiologie de la fièvre typhoïde, Paris, 1885.
[6] Bulletin Société d'Anatomie, December, 1886.

of the bacillus on medium of diminished nutritive power. The typhoid bacillus grown on gelatine acidified with a few drops of a 5 per cent. solution of carbolic acid, which retards its development, showed a non-stained space in the center; while bacilli taken from the same original culture, when grown on ordinary gelatine in the same length of time, gave the cylindrical form.

Moreover, Chantemesse and Widal[1] have found several water species, and Blocq[2] has discovered an air species, which present such a non-stained center. Although this characteristic does not possess the diagnostic value attributed to it by Artaud, it is not to be neglected. On account of its appearance when the bacillus is grown on potato and acidified gelatine, it is entitled to a place in the series of characteristics which enable the bacteriologist to identify the bacillus of typhoid fever. This point will be again alluded to under spore formation.

MOTILITY.— The energetic motion, when examined in a hanging drop, is one of the most important characteristics of this bacillus. It not only moves about in the field of the microscope, but has a distinct vibratory motion around its axis. This was thought to be due to cilia, as was shown to be the case with large motile bacteria by Koch and Neuhauss. By means of a special staining method, Loeffler[3] was able to show the presence of cilia on the typhoid bacillus. He employed a mordant made by adding, drop by drop, to 10 cc. of a 20 per cent. aqueous solution of tannin, an aqueous solution of ferrous sulphate, till the liquid is violet black; three or four cc. of logwood (one part logwood to eight parts water) are added, giving the liquid a marked violet tint; 5 cc. of a 5 per cent. solution of carbolic acid serves to preserve the solution without affecting its power as a mordant. His stain was made by adding to a saturated aqueous solution of aniline, 1 cc. of a 1 per cent. solution of NaOH and 4 to 5 grams of methylene blue or fuchsine, as desired. The coloring material goes into solution on shaking, and the solution is then sterilized. Cover slips are prepared in the usual manner, the mordant added and heated gently till steam is evolved. The mordant is then washed off, two or three drops of the coloring agent added and heated gently until

[1] Archives de Physiologie, March, 1887.
[2] Referred to by Chantemesse and Widal.
[3] Centralblatt für Bakteriologie, 1888, p. 209. Referred to by Gasser, *loc. cit.*

sufficient coloration is obtained. The preparation is then washed, dried, and mounted.

More recently Loeffler[1] has confirmed his work, finding the typhoid bacillus to possess several cilia, very fragile, easily detached, and appearing particularly in cultures five to eight hours old, on freshly coagulated blood serum. Babes[2] has confirmed Loeffler's investigations, finding the bacillus to possess five to twenty cilia, sometimes found in bunches at one end or side, and sometimes distributed unevenly along the sides or ends.

Spore Formation.— The formation of spores by the typhoid bacillus has been much discussed. Gaffky[3] found at the end of the bacillus, small, clear, refracting spheres, which were not stained by aniline colors. These forms occurred regularly when the bacillus was grown at 37° C. on potato or agar. After drying many months it showed a luxuriant growth when transferred to culture medium. This admitted, at least, the possibility of true spore formation; and, after comparison with the spore formation in other species, led Gaffky to conclude that they were true spores. However, the shining bodies of uniform size within the bacillus, which one is accustomed to see, were wanting.

Seitz,[4] after growing the bacillus on potato, bouillon, and agar, two to five days, at the body temperature, was unable to confirm Gaffky's observations. Chantemesse and Widal[5] grew the bacillus on potato at 38° C., and after four or five days observed, at the ends, oval-shaped bodies of a diameter greater than that of the bacillus itself. They were not affected by the aniline colors.

Buchner[6] showed that the typhoid bacillus, grown at 37° C. on potato, presented at its extremities clear, refracting spheres, apparently spores. He also proved that these spores were more readily formed when the bacillus was cultivated on acid potato, agar deprived of oxygen, and other media not favorable for growth. This led him to think that a form of involution existed. The so-called terminal spores he found to stain more intensely and more rapidly than the bacillus itself. He concluded from his experiments that there was

[1] Centralblatt für Bakteriologie, 1890, p. 625.
[2] Zeitschrift für Hygiene, Bd. IX, p. 323.
[3] *Loc. cit.*
[4] Centralblatt für klinische Medicin, 1887, p. 267.
[5] Archives de Physiologie, March, 1887.
[6] Centralblatt für Bakteriologie, 1888, pp. 353 and 385.

no spore, but a contraction of protoplasm; and that in consequence, either at the ends or at the center of bacillus, *after staining*, non-stained vacuoles were formed.

This explains the non-stained, central vacuoles mentioned above, which caused much controversy among bacteriologists during the preceding years.

Further biological argument was shown by the fact that these bacilli offer less resistance to drying and the action of heat than those not possessing this non-stained vacuole formation. This work was verified by Pfuhl,[1] who arrived at the same conclusions.

Vaillard and Vincent[2] cultivated the typhoid bacillus, obtained from the spleen of a typhoid fever victim, on human spleen bouillon. They found at the end of sixty days a large number of bacilli of varying length, the greater number exceeding 120 $\mu$, possessing a linear series of bright refracting bodies not stained by the aniline colors. The bacillus grown in the same bouillon did not show these bodies after sixteen days. They found that these vacuolated filaments were killed by heating for ten minutes to 54° C., while the ordinary typhoid bacillus was killed by heating for ten minutes to 55° C.

Birch-Hirschfeld[3] found that 1 cc. of 1 per cent. solution of rosaniline, added to 10 cc. of nutrient gelatine, colored rounded masses within the bacillus. This he thought favored the idea of true spore formation.

The indications at the present time, however, resulting from morphological and physiological experiments, are that the bacillus does not form true spores.

Biology.— Janowski[4] has contributed some interesting experiments on the influence of light and temperature upon the typhoid bacillus. After inoculating a number of gelatine tubes, he placed them in a cool room, near a window through which the sun did not shine, and wrapped a portion of them in a dark, thick paper. These latter he found showed a growth in three days, while those exposed to the rays of light required five days for the appearance of growth. After six hours' exposure to the direct rays of the sun, freshly inoculated bouillon proved sterile. To show that no chemical change

[1] Centralblatt für Bakteriologie, 1888, p. 769.
[2] *Loc. cit.*
[3] Archiv für Hygiene, 1888, p. 341.
[4] Centralblatt für Bakteriologie, 1890, Bd. VIII, Nos. 6–9, 14 and 15.

had taken place in the medium, he again inoculated the same bouillon under the usual conditions, and obtained the normal growth. That this was not due to heat was indicated by the fact that the maximum temperature never exceeded 40.5° C. — but little above its optimum temperature.

The author concluded that this effect was produced by the chemical action of direct sunlight. In support of this, he placed tube cultures in flasks containing a solution of bismarck brown or of potassium bichromate, through which the blue, violet and ultra violet rays do not pass, and in all cases obtained the normal growth; while tube cultures placed in flasks containing solutions of fuchsine or methyl violet, through which the blue, violet and ultra violet rays pass, proved sterile.

For studying the action of high temperatures on the typhoid bacillus, he used a double-walled, felt-covered water bath, by means of which he could maintain a constant temperature for fifteen minutes. The apparatus was so arranged that the tube of gelatine could be inoculated while remaining in the water bath. After removal from the hot water, the tubes were rolled after Esmarch's method. In this manner Janowski found that the bacilli were killed usually in ten minutes at 56° C., and in all cases in ten minutes at 57° C. These results agree with those of Sternberg.[1] Pfuhl, Buchner, and others had obtained a somewhat lower temperature, but their method — placing the bacilli on a sterilized needle in hot air — was less accurate.

He confirmed Prudden's[2] statement that the bacillus is killed by alternate freezing and thawing of the culture in a mixture of calcium chloride and ice.

The actual effect of winter weather was studied by placing a bouillon culture, January 17, in snow, which then covered the ground, and daily removing a small portion of the frozen bouillon for examination. With the changing temperature of the air, the bouillon was frozen and thawed many times, but showed a growth until February 5. The night of February 4 was extremely cold, the temperature of the air being lower than 0° C., while that of the snow was 14° C. The culture showed no further growth. Prudden, however, found the bacillus capable of growth after having been frozen in ice for 103 days.

[1] Medical News, April 30, 1887.
[2] Medical Record, 1887.

The life and growth of the typhoid bacillus in water, sewage, and soil, has not as yet been thoroughly studied. A clue to the present state of our knowledge upon the subject can be obtained from the following brief outline:

The typhoid bacillus apparently does not multiply in water, sewage, or soil. In sewage the duration of life varies from four days[1] to three months.[2] In soil it has been found by Grancher and Deschamps[3] after 5½ months, and in the region of a suspicious well it was found by Macé[4] at a depth of 2 – 3 meters. The varying length of life is not fully understood. Karlinski[5] concludes that temperature does not affect continuation of life. Straus and Dubany[6] infer from their experiments that the chemical composition of a water possesses no appreciable influence upon the duration of the life of the typhoid bacillus in the given water. The majority of investigators in this subject, particularly in its relation to drinking water, however, have failed to face the problem as it exists in nature; that is to say, having worked with sterilized water and with sterilized sewage, they have wholly overlooked the complications which arise with the presence of the ordinary species of water and sewage microorganisms.

### THE CULTIVATION OF THE TYPHOID BACILLUS.

The typhoid bacillus can be grown in culture media at temperatures varying from 10° C. to 46° C.[7] Its optimum temperature, however, lies between 37° C. and 39° C.

It is a facultative anaërobe; that is to say, it grows most readily and most characteristically in the presence of oxygen, although the absence of oxygen, while retarding its development, does not wholly prevent its growth.

The typhoid bacillus shows a growth on the gelatine plate in the usual time, 48 – 72 hours, at the temperature of the room. The colonies lying deep in the gelatine are small, white, circular or spindle-shaped, and sharply outlined. The surface colonies are larger,

[1] Schiller, Arbeiten aus dem Kaiserlichen Gesundheitsamtes, Bd. VI, p. 197.
[2] Uffelmann, Centralblatt für Bakteriologie, 1889, Bd. V, p. 497.
[3] Archives de Médecine Expérimentale, T. I, p. 33.
[4] Comptes rendus, Académie des Sciences, T. CVI, p. 1546.
[5] Centralblatt für Bakteriologie, Bd. VI, No. 3, p. 65.
[6] Archives de Médecine Expérimentale, T. I, p. 5.
[7] Gasser, *loc. cit.*

spreading out into a thin, bluish, transparent skin, with irregular outline, often appearing yellowish in the center; and when seen under the microscope usually exhibit markings similar to the veining of a leaf. When viewed by transmitted light, the colonies give a yellowish brown color. They are very similar to the colonies of coli commune — a species common in fæces. The similarity is even more marked when examined under the microscope. Coli commune, however, usually grows more quickly and forms larger colonies.

When grown in a gelatine tube, small round colonies, very closely joined together, appear along the inoculation line. At the surface appears a thin, grayish, shining skin, which spreads to the wall of the tube. When a tube of melted gelatine is solidified so as to give an inclined surface, the surface growth following inoculation can be well observed. On both sides of the inoculation line it gives a thin, nearly transparent, shining, bluish-white coating of irregular outline. The intensity of growth is somewhat variable, and is attributed by Seitz to the greater or less alkalinity of the culture medium. Garré[1] observed a curious feature of its growth on gelatine, namely: if all growth is removed by a sterile needle from a tube, and the tube again inoculated, it remains sterile — the gelatine being apparently "vaccinated." This has been confirmed by several French bacteriologists.

On agar and blood serum it gives a moist, white growth, showing no special characteristics.

In bouillon it forms a slight uniform turbidity and considerable yellowish-white dusty sediment.

It is on sterilized potato that it shows its most marked characteristic. In two days at the body temperature, or three to four days at room temperature, the inoculated potato gives a luxuriant but to the unaided eye completely invisible growth. The entire surface of the potato assumes a moist, shining appearance, but is not otherwise changed. If a small portion is removed with a sterilized platinum needle, and examined in a drop of water under the microscope, a large number of bacilli, moving about very energetically, are to be seen. It was thought at one time that this was a method of differentiation from all other species. Several investigators, however, have found that this characteristic is obtained only when the bacillus is grown on slightly acid potato; slightly alkaline potato gives a

[1] Correspondenzblatt für Schweizerische Aerzte, 1887.

gray or yellow growth along the inoculation line. This point has been carefully studied by Schiller,[1] who confirmed the variable growth on potato. Moreover, a few species, particularly water species, have been found which give a similarly invisible growth on potato, showing that this is not an absolute method of differentiation.

### SPECIAL METHODS AND MEDIA FOR CULTIVATION.

Many efforts have been made to devise some new method of procedure which shall furnish unfailing means for identification. Chantemesse and Widal[2] used nutrient gelatine, containing 0.2 per cent carbolic acid, which they claim prevents the growth of nearly all other species, but does not retard the growth of the typhoid bacillus. Thinot[3] added 0.25 grms. of carbolic acid to 100 cc. of the water which he wished to examine. Petruschky[4] considered the formation of acid to be of diagnostic value. Holz[5] added 10 per cent. of gelatine to the juice of raw potatoes, obtaining a solid, transparent, slightly acid medium, on which the typhoid bacillus grows quite characteristically, while nearly all other species refuse to grow, particularly if 0.05 per cent. carbolic acid is added. Kitisato[6] found that typhoid and some other species (he gives a list) give a negative indol reaction, while many water and sewage species produce the characteristic red coloration, when to a bouillon culture grown for 24 hours at 37° C. are added 1 cc. of a solution containing 0.02 grm. $NaNO_2$ in 100 cc. and a few drops of concentrated $H_2SO_4$. This fact he considers of much diagnostic value in some cases.

These methods have all been carefully studied, and none have proved to be a trustworthy means for the identification of the typhoid bacillus.

Gasser[7] has recently made some experiments with colored gelatine. He found only two species — coli commune and typhoid — which decolorized gelatine colored by a few drops of fuchsine. These can be readily differentiated, he says, by the fact that coli commune

[1] Arbeiten aus dem Kaiserlichen Gesundheitsamtes, Bd V, p. 312.
[2] Archives de Physiologie, March, 1887, p. 217.
[3] La Semaine Médicale, 1887, No. 14, p. 135.
[4] Centralblatt für Bakteriologie, Bd. VI, 1889, p. 660.
[5] Zeitschrift für Hygiene, Bd. VIII, p. 148.
[6] Zeitschrift für Hygiene, Bd. VII, p. 515.
[7] Archives de Médecine Expérimentale, November, 1890.

decolorizes the gelatine in two to three days, while typhoid requires six to eight days. Moreover, on colored agar the coli commune growth is confined to the inoculation line, while the typhoid growth is diffused through the neighboring medium. I have tried this method, but was unable to find decolorization by the typhoid bacillus, even after allowing the inoculated plates to remain sixteen days.

Noeggerath[1] has proposed the use of gelatine colored by the following mixture of aniline colors:

| | |
|---|---|
| Saturated aqueous solution of methylene blue | 2 cc. |
| " " " gentian violet | 4 " |
| " " " methyl green | 1 " |
| " " " chrysoidine | 4 " |
| " " " fuchsine | 3 " |
| Distilled water | 200 cc. |

The typhoid bacillus gives complete decolorization in fifteen days. This method has been tried by different investigators with varying results, and definite conclusions as to its real value have not yet been reached.

Rodet[2] has suggested cultivation at 44.5° C. This temperature enables the typhoid bacillus to grow, but destroys nearly all other organisms.

Vincent[3] gives a modification of this method, which is especially adapted to the examination of a suspicious drinking water. He uses bouillon containing one drop of carbolic acid to every 2 cc. After mixing with the water he cultivates at 42° C. If, after twelve hours, the solution remains clear, he claims that the typhoid bacillus is not present. But if a turbidity appears, he transplants a small portion to a fresh tube, and so on, until he obtains a pure culture, from which he learns the characteristics of the suspected organism after the methods outlined above.

Péré[4] has very recently published a similar method, which he used with success in the examination of service water at Alger. Into a liter flask he puts 100 cc. of neutral, sterile bouillon, containing equal parts meat juice and water; 50 cc. of a neutral, sterile, 10 per cent. peptone solution; 600 to 700 cc. of water to be examined; 20 cc. of a 5 per cent. carbolic solution, and then fills the flask with

[1] Fortschritte der Medicin, 1888, Bd. VI.
[2] Comptes rendus, Société Biologique, T. II, No. 8. Blyth's Manual of Public Health, p. 496.
[3] *Ibid.*, T. II, No. 5. *Ibid.*, p. 497.
[4] Annales de l'Institut Pasteur, 1891, p. 79.

the suspected water. He then puts this liquid into ten sterile flasks, and keeps them at approximately 34° C.— within the limits of 32° C. and 36° C. From this point his method is identical with that of Vincent. He claims that coli commune and the typhoid bacillus are the only organisms which develop by this procedure.

It is very important to note that the growth of the typhoid bacillus on each of the different culture media is more or less variable; and a definite opinion concerning its identity can be obtained only from a careful study of its growth on all the culture media. Moreover, Babes,[1] in his careful study on the "Variability and Varieties of the Typhoid Bacillus," states that the bacillus becomes larger when grown on gelatine and potato than when grown on agar. Many times he found the gelatine and potato cultures contained bacilli 0.7 $\mu$ in diameter.

### INOCULATION OF ANIMALS.

The first experiments on the inoculation of the lower animals with pure cultures of the typhoid bacillus were made by Gaffky.[2] He infected more than sixty animals, including guinea pigs, monkeys, rabbits, white rats, gray mice, field mice, pigeons, chickens, and calves. His inoculations were made in the veins or in the peritoneal cavity. After a long time death followed, in some cases from a general breaking-down of the system; but in no case did the autopsy show any connection with typhoid fever.

On the other hand, E. Fraenkel[3] and Simmonds inoculated in the auricular veins a large number of rabbits; one half of them died in twenty-four to forty-eight hours, showing a swelling in the spleen, mesenteric glands, and intestinal follicles. Examination showed the bacillus in the spleen, but they did not usually pass into the intestines.

Iwan Michael,[4] Fodor,[5] and Seitz,[6] confirmed these experiments. Seitz, moreover, prepared some guinea pigs after the method used by Koch to facilitate cholera infection; that is to say, he rendered the contents of the stomach alkaline with sodium carbonate, and

[1] *Loc. cit.*
[2] *Loc. cit.*
[3] Die Aetiologische Bedeutung des Typhus-Bacillus, Hamburg, 1886.
[4] Fortschritte der Medicin, 1886, p. 353.
[5] Deutsche medicinische Wochenschrift, 1886, No. 36.
[6] Bakteriologisches Studium zur Typhus Aetiologie, München, 1886.

retarded the movement of the intestines by opium. Into the stomach of part of them he injected the fæces of a typhoid patient. The majority died and gave symptoms identical with those of the animals which died from an injection of a pure culture of typhoid bacilli. The spleen and mesenteric glands were swollen, and the intestines much changed. The intestines and some of the other organs contained typhoid bacilli; the blood was free. Into the remainder of the animals, however, he injected the fæces of a person in good health, and no effect was observed.

A. Fraenkel[1] also confirmed these results, inoculating fourteen guinea pigs in the duodenum, after the method of Nicate and Rietsch. He obtained seven positive results — the animals dying in three to seven days. The autopsies showed the condition of intestines and other organs to be similar to those mentioned above. He also noted in one case a round ulceration a half centimeter in diameter.

Contradictions were not slow to appear. Sirotinin[2] and Beumer and Peiper[3] simultaneously published results directly opposed to the above. Sirotinin did not deny that animals inoculated with typhoid bacilli died after a few hours; but he claimed that death was not caused by typhoid fever, but by a poisoning by the ptomaïne. He found that the ptomaïne extracted from sterilized cultures produced the same effect as the living bacilli. The success of the experiment depends upon the quantity of material injected, the chemical composition of the culture medium, and the age of the culture. The increase in the number of bacilli, noted by former investigators, he was unable to confirm. He claimed that the injected bacilli pass rapidly away, and an increase in numbers is to be found only when the autopsy is delayed, thereby enabling the few remaining bacilli, in such organs as the spleen, to multiply rapidly.

Beumer and Peiper confirmed these conclusions and found, moreover, that death could be produced in mice, rabbits, and guinea pigs, by the inoculation of ordinary water species such as bacillus subtilis, micrococcus prodigiosus, white bacillus,[4] and the liquefying fluorescent bacillus.[5] They conclude, without hesitancy, that it is not possible to produce typhoid fever in the lower animals.

[1] Centralblatt für klinische Medicin, 1886, No. 10.
[2] Zeitschrift für Hygiene, Bd. I, p. 465.
[3] *Ibid*, Bd. I, p. 489.
[4] No. 19, Eisenberg's Tabellen (Erste Auflage).
[5] No. 6, Eisenberg's Tabellen (Erste Auflage).

PTOMAÏNE.

The discovery of ptomaïnes (alkaloids formed by bacteria during the putrefaction of organic matter) opened a new and important field in experimental medicine. The ptomaïne of the typhoid fever bacillus was discovered by Brieger,[1] and named typhotoxine. He obtained it by cultivating the bacillus on beef broth for eight to fourteen days at the temperature 37.5° C. – 38° C. The following outline of his method of procedure is taken from Vaughan and Novey.[2]

The beef broth culture is first treated for a few minutes with water slightly acidified with hydrochloric acid, care being taken that the feebly acid reaction is maintained. The liquid is then filtered and concentrated, at first on a plate and then on a water bath, to a syrup; an extraction made with 96 per cent. alcohol, and the filtered extract treated with a warm alcholic solution of lead acetate. The lead precipitate is removed by filtration; the filtrate evaporated to a syrup and again extracted with 96 per cent. alcohol. The alcohol is driven off and the residue taken up with water. After removal of traces of lead by hydrogen sulphide, the filtrate is acidified with hydrochloric acid and evaporated to a syrup. This syrup is extracted with alcohol, and the filtrate treated with an alcoholic solution of mercuric chloride. The ptomaïne $C_7H_{17}NO_2$ is obtained as an easily deliquescent hydrochloride from this precipitate after removal of the mercury by hydrogen sulphide. For purification it is converted into the difficultly soluble aurochloride.

Typhotoxine is isomeric with the compound $C_7H_{17}NO_2$, which Brieger obtained from putrefying horseflesh. Its properties, however, are very different.

The following chemical properties, which distinguish typhotoxine from all other alkaloids, have been noted by Luff[3] and referred to by Gasser.[4] It crystallizes as a white powder. Its hypochlorate, in solution, gives a white precipitate with phosphomolybdic acid; with picric acid and gold chloride, a yellow precipitate; with sodine solution, a dark-colored precipitate; with tannic acid, a dark yellow precipitate. It gives no reaction with phosphowolframic acid, or with platinic chloride.

[1] Weitere Untersuchungen über Ptomaïne, 1885.
[2] Ptomaïnes and Leucomaïnes, 1888.
[3] British Medical Journal, July 27, 1889.
[4] *Loc. cit.*

Its physiological action has been studied on mice and guinea pigs.[1] It produces at first slight salivation, increased respiration, and a paralytic condition of the muscles; salivation increases; heart action and respiration decrease, and the animal dies in from one to two days. Diarrhœic evacuations are frequent throughout, but at no time are convulsions present as in the case of the isomer extracted from putrefying horseflesh.

In conclusion, it is to be said that, at the present time, no single characteristic of the typhoid fever bacillus, other than its ptomaïne, is known which is not possessed by at least one other bacillus; but by taking all of its characteristics together, an expert bacteriologist can obtain a very clear picture of it. During the first few years following its discovery, its characteristics were sufficient to differentiate it from all other bacteria then known; but, with the rapid progress in bacteriology and the more careful study of the water and sewage microörganisms, each of its characteristics was found to be possessed by other species.

The exact state of our knowledge of the typhoid fever bacillus has been well expressed by Koch[2]: "When the typhoid fever bacillus is found in the mesenteric glands, spleen, or liver of a typhoid fever victim, there can be no doubt that one is dealing with the genuine typhoid fever bacillus; for other bacteria have never been found in these places which could be confused with it. But the conditions are wholly changed if it is attempted to identify the typhoid fever bacillus in fæces, soil, water, and dust. For there are found here great numbers of very similar bacteria which only a very skilled bacteriologist can distinguish from the typhoid fever bacillus; and, even then, not with absolute certainty, since unmistakable and constant characteristics are as yet lacking. The numerous statements recently made, that the typhoid fever bacillus has been found in soil, drinking water, and foods, can therefore be received only with a reasonable doubt."

LAWRENCE EXPERIMENT STATION,
MASSACHUSETTS STATE BOARD OF HEALTH,
*June 1, 1891.*

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[1] Vaughan and Novey, *loc. cit.*

[2] Ueber bakteriologische Forschung. Vortrag. Internat. Med. Congress, August, 1890.

# *ON THE CANDLE-POWER OF INCANDESCENT LAMPS AS RELATED TO CURRENT, VOLTAGE, AND ENERGY CONSUMED.*[1]

By LOUIS A. FERGUSON and DAVID A. CENTER.

The observations described in the present paper have for their object the study of the relation between the illuminating power of various incandescent lamps now in use, and the current, potential, and expenditure of energy used in operating them. The observations were made in the spring of 1888, but various circumstances have delayed their publication till the present time.

The subject has already been considered by several persons, and it has appeared that for such lamps as have been tested the candle-power is approximately proportional to the cube of the current, and to the fifth power of the potential difference between the terminals of the lamp. It seemed to us, however, that it was desirable to carry out a series of tests with more recent lamps, and with a greater variety of them than had been employed in former experiments upon the subject. It was also thought that a consideration of the relation between the candle-power and the potential difference between the terminals of the lamp (or electrical pressure) would be useful.

We considered it best, on the whole, to express our results in the form of a simple exponential equation of the form $y = ax^n$, as has been customary, notwithstanding the fact that, as Götz has shown,[2] at least for the relation between candle-power and energy expended, the results of experiments are more accurately expressed by an equation of the form $y = ax + bx^n$.

The greater simplicity of the common formula has decided advantages in its practical application which go far to make up for

[1] Read at a meeting of the American Academy of Arts and Sciences, June 11, 1890.

[2] Centralblatt für Elektrotechnik, v. 5, p. 720.

the somewhat diminished accuracy at extreme values of the candle-power, while within quite wide ranges it is amply exact for all practical purposes.

There were tested in all twenty-one lamps, including those made by the Edison, United States, Thomson-Houston, and Westinghouse companies, having in every case a good normal filament. The photometric measurements were made with a Bunsen photometer. The lamp to be tested was placed in the circuit of an Edison or Westinghouse direct current dynamo, from either of which machines an electromotive force of 110 volts could be obtained, and by coupling the two machines in series the lamp could be put into a circuit having a potential of 220 volts.

In the same circuit with the lamp to be tested was placed a Thomson graded current galvanometer, by which the current could be measured with ease within one per cent. The difference of potential at the terminals of the lamp was measured by a Thomson potential galvanometer, whose readings also could be depended upon to at least one per cent. The product obtained by multiplying the current in ampères by the difference of potential at the terminals of the lamp in volts, gave the rate in watts at which energy was consumed in the lamp at any given time.

The necessary variation in the current and electromotive force in the working circuit was accomplished by means of a set of six Edison lamps placed in the circuit, with connections between the lamps so arranged that any number of lamps could be thrown out of circuit at a time, or two or three thrown in parallel with each other, thus giving a wide range of variation of resistance. For smaller variations a set of German silver resistance coils was constructed, and arranged so that changes from one fourth of an ohm up to 75 ohms could readily be secured. A Methven slit was used as a standard of light.

In all cases except with those of the United States Company, the lamps were placed so that the plane of the filament was at right angles to the plane of the bar. They were kept in this position throughout the test. The United States lamps were placed so that the plane of the filament made an angle of 45° with the bar.

The lamps were first started at about two tenths of a candle-power, the resistance in circuit then being decreased until a suitable reading was obtained on the photometer, when a series of

twelve or more readings was made of the candle-power by one observer, while the other, as often as possible during the interval, read the current in the circuit and the potential at the terminals of the lamp. The resistance was again changed and new measurements taken of the candle-power, current, and potential, this mode of procedure being continued in most cases until the filament gave way. In some cases it was not broken in the first test, and a second run on the lamps was made. In every such instance it was found that the curve of relation ran lower than in the first test, showing that the effect upon the lamp was to decrease its efficiency, more energy per candle being consumed in the second run. It was also found, in a few instances where it was impossible to finish a test of the lamp on the same day that it was begun, that on resuming the test it required more energy per candle than on the first day, until after some fifteen minutes had elapsed, when the original values were again obtained. This is clearly seen in the Thomson-Houston 32 candle-power, 52 volt lamp denoted in the tables by the letter M.

As a matter of some interest, several tests were made upon some of the Edison lamps to find out, if possible, about how much energy must be expended in such a lamp in order that the first appearance of light might be distinguished with the naked eye in a positively dark room. It was also thought to be of interest to know the color of the light in this case. Measurements were made of the current and potential, and it was found that the mean value of the energy expended when the light first became visible to the most sensitive observer was about 0.74 watts. The color of the light emitted by the filament was in all cases of an ashy gray.

Nearly every style of lamp seemed to have one particular place at which the filament gave way. The Edison filament, in every instance but one, broke at from one eighth to one half an inch above the platinum joint on the right hand side, looking at the labelled side of the globe. The circuit wires were removed from the lamp-socket before this fact was noted, so that we are unable to state whether this was the positive or negative side. The filament of the Weston lamps always broke at about one inch from the top, while that of the Thomson-Houston lamps broke at the top. One of the Westinghouse lamps broke at about one eighth of an inch above the middle point of the right-hand side of the filament, looking

at the labelled side of the globe; another broke at about one eighth of an inch above the joint on the same side. In nearly all the lamps tested the joints were noticed to be very black, due to deposition of carbon by the Crookes' effect.

A series of curves was constructed showing graphically the relations between the candle-power and the current, potential, and energy expended, and equations of the form $y = ax^n$ satisfying the observed values of the variables were determined by the method of least squares for the various lamps in the case of the current and energy determinations. In these the candle-power is denoted by $y$ and the other variable by $x$. From these equations others, giving the relation between the potential and candle-power, were calculated. This calculation, together with other aid in the preparation of some of our tables, we owe to the kindness of Mr. Edward Collins, Jr., of the Rogers Laboratory.

We had observed that in nearly all cases as the lamp approached the breaking-point the curve ceased to run up with its usual steepness, the candle-power falling off very rapidly. In the calculations of the equation for each lamp, all observations above this point at which the curve fell off were neglected as being of no value for our determinations. This we felt justified in doing, since our object was to deduce an equation which would show the relation between the candle-power and current, or other variable, as long as the former increases regularly with the latter.

In the tables appended the lamps used are designated alphabetically. We calculated the equation for each separate lamp, and from these deduced, by the usual method, a general equation applying to each particular kind of lamp. Below are given the individual equations, as well as the general equations calculated from them.

The Edison lamps used were of the "new style," 3.1 watts per candle-power, and the Weston lamps were the "tamadine lamps."

EDISON, 16 C.P., 110 V.

(A) $y = 500\, x^{5.3}$
(B) $y = 540\, x^{5.0}$
GENERAL EQUATION $v = 520\, x^{5.1}$

EDISON, 10 C.P., 110 V.

(C) $y = 490\, x^{4.7}$

WESTON, 16 C.P., 110 V.

(D) $y = 154\ x^{5.0}$
(E) $y = 160\ x^{4.9}$
GENERAL EQUATION $y = 157\ x^{4.95}$

WESTINGHOUSE, 16 C.P., 50 V.

(F) $y = 7.7\ x^{5.8}$
(G) $y = 6.7\ x^{5.4}$
GENERAL EQUATION $y = 7.21\ x^{5.6}$

THOMSON-HOUSTON, 16 C.P., 75 V.

(H) $y = 71.5\ x^{6.2}$
(J) $y = 68.9\ x^{5.6}$
GENERAL EQUATION $y = 74\ x^{5.9}$

THOMSON-HOUSTON, 16 C.P., 60 V.

(K) $y = 124\ x^{5.48}$
(L) $y = 124\ x^{5.42}$
GENERAL EQUATION $y = 124\ x^{5.45}$

THOMSON-HOUSTON, 32 C.P., 52 V.

(M) $y = .258\ x^{5.9}$
(N) $y = .310\ x^{5.5}$
GENERAL EQUATION $y = .284\ x^{5.7}$

THOMSON-HOUSTON, 20 C.P., 110 V.

(O) $y = 67.5\ x^{4.8}$
(P) $y = 91.0\ x^{5.2}$
GENERAL EQUATION $y = 70.2\ x^{5}$

In like manner were obtained the relations between the candle-power and the energy expended, which are as follows:

EDISON, 16 C.P., 110 V.

(A) $y = 0.000065\ x^{3.1}$
(B) $y = 0.000131\ x^{2.9}$
GENERAL EQUATION $y = 0.000098\ x^{3}$

EDISON, 10 C.P., 110 V.

(C) $y = 0.000087\ x^{3}$

WESTON, 16 C.P., 110 V.

(D) $y = 0.000069\, x^{2.9}$
(E) $y = 0.000051\, x^{3}$
GENERAL EQUATION $y = 0.000059\, x^{2.9}$

WESTINGHOUSE, 16 C.P., 50 V.

(F) $y = 0.00016\, x^{2.8}$
(G) $y = 0.00026\, x^{2.7}$
GENERAL EQUATION $y = 0.000208\, x^{2.7}$

THOMSON-HOUSTON, 16 C.P., 75 V.

(H) $y = 0.000157\, x^{2.8}$
(J) $y = 0.000153\, x^{2.8}$
GENERAL EQUATION $y = 0.000155\, x^{2.8}$

THOMSON-HOUSTON, 16 C.P., 60 V.

(K) $y = 0.00062\, x^{2.7}$
(L) $y = 0.00015\, x^{3.1}$
GENERAL EQUATION $y = 0.00031\, x^{2.9}$

THOMSON-HOUSTON, 32 C.P., 52 V.

(M) $y = 0.000020\, x^{3}$
(N) $y = 0.000098\, x^{2.6}$
GENERAL EQUATION $y = 0.000059\, x^{2.8}$

THOMSON-HOUSTON, 20 C.P., 110 V.

(O) $y = 0.00016\, x^{2.6}$
(P) $y = 0.000059\, x^{2.9}$
GENERAL EQUATION $y = 0.00011\, x^{2.7}$

The following equations showing the relation between the candle-power and potential difference between the lamp terminals, as already stated, were calculated from the preceding equations, except in the case of (F) (G) (P), which were obtained directly from the observed results.

EDISON, 16 C.P., 110 V.

(A) $y = 0.000\,000\,000\,000\,021\, x^{7.3}$
(B) $y = 0.000\,000\,000\,000\,151\, x^{6.8}$
GENERAL EQUATION $y = 0.000\,000\,000\,000\,0082\, x^{7.4}$

EDISON, 10 C.P., 110 V.

(C) $y = 0.000\,000\,000\,000\,000\,18\, x^{8.2}$

### WESTON, 16 C.P., 110 V.

(D) $y = 0.000\,000\,000\,000\,11\ x^{6.9}$
(E) $y = 0.000\,000\,000\,000\,01\ x^{7.4}$
GENERAL EQUATION $y = 0.000\,000\,000\,000\,033\ x^{7.1}$

### WESTINGHOUSE, 16 C.P., 50 V.

(F) $y = 0.000\,000\,0036\ x^{5.6}$
(G) $y = 0.000\,000\,0047\ x^{5.5}$
GENERAL EQUATION $y = 0.000\,000\,0041\ x^{5.6}$

### THOMSON-HOUSTON, 16 C.P., 75 V.

(H) $y = 0.000\,000\,0037\ x^{5.1}$
(J) $y = 0.000\,000\,000\,3\ x^{5.7}$
GENERAL EQUATION $y = 0.000\,000\,0011\ x^{5.4}$

### THOMSON-HOUSTON, 16 C.P., 60 V.

(K) $y = 0.000\,000\,0034\ x^{5.4}$
(L) $y = 0.000\,000\,000\,1\ x^{7.4}$
GENERAL EQUATION $y = 0.000\,000\,000\,065\ x^{6.4}$

### THOMSON-HOUSTON, 32 C.P., 52 V.

(M) $y = 0.000\,000\,001\ x^{5.9}$
(N) $y = 0.000\,000\,059\ x^{5.0}$
GENERAL EQUATION $y = 0.000\,000\,0089\ x^{5.5}$

### THOMSON-HOUSTON, 20 C.P., 110 V.

(O) $y = 0.000\,000\,000\,038\ x^{5.7}$
(P) $y = 0.000\,000\,000\,000\,01\ x^{7.5}$
GENERAL EQUATION $y = 0.000\,000\,000\,000\,62\ x^{6.6}$

The following tables give the data from which the various preceding computations have been derived. They also indicate the deviations of results calculated by the individual formulas from the observed values. The current, potential differences, and energy expended are given in the first three columns headed *C.*, *P. D.*, *E.*, respectively. The fourth column contains the observed candle-power. The remaining columns indicate the candle-power calculated from the current, potential difference, and energy, respectively, together with the deviation of the calculated from the observed values.

EDISON LAMP. 16 C.P. 110 VOLTS. (A)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .245 | 62.52 | 15.32 | .20 | .30 | —.10 | .24 | —.04 | .27 | —.07 |
| .271 | 69.02 | 18.70 | .46 | | | | | | |
| .304 | 75.19 | 22.86 | .97 | .93 | .03 | .93 | .04 | .93 | .04 |
| .348 | 84.14 | 29.28 | 2.23 | | | | | | |
| .374 | 88.06 | 32.93 | 3.28 | | | | | | |
| .425 | 97.52 | 41.45 | 6.56 | 5.96 | .60 | 6.13 | .42 | 5.76 | .80 |
| .468 | 105.60 | 49.42 | 10.74 | | | | | | |
| .479 | 107.43 | 51.46 | 12.10 | | | | | | |
| .494 | 109.96 | 54.32 | 15.19 | | | | | | |
| .568 | 117.34 | 66.65 | 24.96 | 25.29 | —.33 | 23.56 | 1.40 | 24.60 | .36 |
| .598 | 120.95 | 72.33 | 31.69 | | | | | | |
| .638 | 126.33 | 80.60 | 42.06 | 46.69 | —4.63 | 40.35 | 1.71 | 44.03 | —1.97 |
| .683 | 136.02 | 92.90 | 60.25 | | | | | | |
| .703 | 139.27 | 97.91 | 69.71 | 78.00 | —8.29 | 81.96 | —12.25 | 74.43 | —4.72 |
| .749 | 145.47 | 108.96 | 87.58 | | | | | | |
| .824 | 158.12 | 130.29 | 113.20 | 180.50 | —67.30 | 112.14 | 1.06 | 191.50 | —78.30 |

EDISON LAMP. 16 C.P. 110 VOLTS. (B)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .235 | 65.05 | 15.29 | .295 | .371 | —.076 | .311 | —.016 | .356 | —.061 |
| .262 | 71.10 | 18.63 | .563 | | | | | | |
| .294 | 76.40 | 22.46 | 1.09 | 1.15 | —.06 | .93 | .16 | 1.09 | 0 |
| .320 | 82.59 | 26.43 | 1.79 | | | | | | |
| .349 | 88.70 | 30.97 | 2.93 | | | | | | |
| .372 | 92.65 | 34.47 | 4.28 | 3.74 | .54 | 3.72 | .02 | 3.76 | .52 |
| .411 | 100.53 | 41.32 | 7.26 | | | | | | |
| .445 | 107.21 | 47.71 | 11.02 | | | | | | |
| .490 | 116.16 | 56.92 | 16.40 | 16.57 | —.17 | 15.97 | .60 | 16.10 | .30 |
| .573 | 129.17 | 74.01 | 30.60 | | | | | | |
| .607 | 134.94 | 81.91 | 41.69 | | | | | | |
| .658 | 143.56 | 94.46 | 61.72 | 65.90 | —4.18 | 67.31 | —1.41 | 69.91 | —8.19 |
| .721 | 156.37 | 112.74 | 88.27 | | | | | | |

EDISON LAMP. 10 C.P. 110 VOLTS. (C)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .202 | 64.49 | 13.03 | .14 | .26 | —.12 | .10 | .04 | .18 | —.04 |
| .293 | 84.82 | 24.85 | 1.37 | | | | | | |
| .341 | 94.81 | 32.33 | 3.08 | 3.10 | .31 | 2.30 | .78 | 2.78 | .30 |
| .395 | 107.85 | 42.60 | 7.97 | | | | | | |
| .433 | 114.84 | 49.73 | 12.22 | 9.54 | 2.68 | 10.93 | 1.29 | 10.03 | 2.19 |
| .507 | 130.13 | 65.98 | 24.17 | 20.05 | 4.12 | 30.35 | —6.18 | 23.33 | .84 |
| .616 | 148.00 | 91.17 | 54.59 | | | | | | |
| .678 | 158.02 | 107.14 | 78.02 | 78.81 | —.79 | 147.40 | —69.40 | 92.18 | —14.16 |

WESTON LAMP. 16 C.P. 110 VOLTS. (D)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .317 | 68.63 | 21.76 | .420 | | | | | | |
| .365 | 76.65 | 27.98 | .695 | 1.034 | — .339 | 1.092 | — .397 | 1.014 | — .319 |
| .409 | 83.86 | 34.30 | 1.66 | | | | | | |
| .458 | 91.24 | 41.19 | 3.57 | 3.21 | .36 | 3.63 | — .06 | 3.09 | .48 |
| .482 | 94.64 | 45.62 | 4.74 | | | | | | |
| .539 | 103.29 | 55.67 | 8.06 | 7.18 | .88 | 8.54 | — .48 | 7.36 | .70 |
| .578 | 108.92 | 62.96 | 11.39 | | | | | | |
| .630 | 115.96 | 73.05 | 18.31 | 15.56 | 2.75 | 18.93 | — .62 | 16.08 | 2.23 |
| .735 | 129.29 | 95.03 | 35.24 | | | | | | |
| .801 | 135.72 | 108.71 | 51.61 | 51.08 | .53 | 55.95 | — 4.34 | 50.54 | 1.07 |
| .877 | 141.21 | 123.84 | 70.47 | | | | | | |
| .977 | 155.40 | 151.83 | 113.69 | 137.22 | — 23.53 | 142.32 | — 28.63 | 132.30 | — 18.61 |

WESTON LAMP. 16 C.P. 110 VOLTS. (E)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .327 | 70.74 | 23.13 | .465 | | | | | | |
| .362 | 76.54 | 27.71 | .863 | 1.078 | —.215 | .885 | —.022 | .951 | —.088 |
| .387 | 81.66 | 31.60 | 1.53 | | | | | | |
| .416 | 86.03 | 35.79 | 2.12 | 2.12 | 0 | 2.10 | .02 | 2.03 | .09 |
| .471 | 94.34 | 44.43 | 4.18 | | | | | | |
| .530 | 102.78 | 54.47 | 7.65 | 6.97 | .68 | 7.85 | —.20 | 7.04 | .61 |
| .593 | 112.30 | 66.59 | 13.23 | | | | | | |
| .629 | 117.51 | 73.92 | 18.72 | 16.24 | 2.48 | 21.13 | —2.59 | 17.36 | 1.36 |
| .755 | 132.28 | 99.94 | 44.16 | | | | | | |
| .800 | 137.48 | 109.98 | 58.33 | 53.28 | 5.05 | 67.54 | —9.21 | 56.30 | 2.03 |
| .899 | 148.32 | 133.34 | 98.23 | | | | | | |
| .987 | 157.68 | 155.94 | 133.72 | 151.87 | —18.15 | 237.40 | —103.68 | 158.06 | —24.34 |
| 1.037 | 166.08 | 172.23 | 144.92 | | | | | | |
| 1.071 | 175.60 | 188.07 | 155.93 | | | | | | |

WESTINGHOUSE LAMP. 16 C.P. 50 VOLTS. (F)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .627 | 28.58 | 17.92 | .426 | .509 | —.083 | .542 | —.116 | .543 | —.117 |
| .684 | 31.12 | 21.29 | .761 | | | | | | |
| .803 | 36.33 | 29.17 | 2.22 | 2.16 | .04 | 2.09 | .13 | 2.16 | .04 |
| .915 | 41.54 | 38.01 | 4.98 | | | | | | |
| .979 | 44.77 | 43.83 | 7.98 | 6.83 | 1.15 | 6.73 | 1.25 | 6.85 | 1.13 |
| 1.089 | 50.12 | 54.58 | 14.74 | | | | | | |
| 1.180 | 53.79 | 63.37 | 22.00 | 20.07 | 1.93 | 18.86 | 3.14 | 19.43 | 2.57 |
| 1.360 | 62.74 | 85.58 | 49.65 | | | | | | |
| 1.440 | 66.74 | 96.11 | 67.50 | 64.57 | 2.93 | 63.36 | 4.14 | 63.14 | 4.36 |
| 1.560 | 73.07 | 113.80 | 98.43 | | | | | | |
| 1.610 | 75.55 | 121.60 | 114.20 | 123.50 | —9.30 | 127.00 | —12.80 | 122.80 | —8.60 |
| 1.700 | 80.76 | 137.50 | 141.50 | | | | | | |

WESTINGHOUSE LAMP. 16 C.P. 50 VOLTS. (G)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .679 | 31.48 | 21.37 | .744 | .831 | —.087 | .780 | —.036 | .874 | —.130 |
| .849 | 38.94 | 33.06 | 2.78 | | | | | | |
| .941 | 42.66 | 40.14 | 4.76 | 4.84 | —.08 | 4.13 | .63 | 4.75 | .01 |
| 1.040 | 47.87 | 49.78 | 8.90 | | | | | | |
| 1.150 | 53.36 | 61.36 | 16.18 | 14.13 | 2.15 | 14.11 | 2.17 | 14.29 | 1.89 |
| 1.320 | 61.19 | 80.77 | 30.76 | | | | | | |
| 1.500 | 69.98 | 105.00 | 59.94 | 59.92 | .02 | 62.53 | —2.59 | 59.32 | .62 |
| 1.500 | 73.08 | 113.30 | 74.46 | | | | | | |
| 1.710 | 80.53 | 137.70 | 115.80 | 123.10 | —7.30 | 135.16 | —29.36 | 121.65 | —5.85 |
| 1.790 | 84.90 | 152.00 | 141.80 | 153.80 | —12.00 | 180.50 | —38.70 | 158.40 | —16.60 |
| 1.930 | 95.60 | 185.60 | 172.40 | | | | | | |

THOMSON–HOUSTON LAMP. 16 C.P. 75 VOLTS. (H)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .414 | 42.80 | 17.72 | .389 | .302 | .087 | .693 | —.304 | .351 | .038 |
| .460 | 48.29 | 22.21 | .855 | .581 | .274 | 1.280 | —.425 | .882 | —.027 |
| .540 | 54.91 | 29.65 | 2.09 | 1.568 | .52 | 2.40 | —.31 | 2.07 | .02 |
| .616 | 61.90 | 38.13 | 4.53 | 3.55 | .98 | 4.51 | .02 | 4.19 | .34 |
| .672 | 67.87 | 45.61 | 7.79 | 6.09 | 1.70 | 7.19 | .60 | 6.92 | .87 |
| .746 | 73.86 | 55.10 | 13.22 | 12.45 | .77 | 11.04 | 2.18 | 11.75 | 1.47 |
| .817 | 79.84 | 65.18 | 20.43 | 20.42 | .01 | 16.38 | 4.05 | 18.40 | 2.03 |
| .938 | 91.80 | 86.11 | 41.94 | 48.10 | —6.16 | 33.25 | 8.69 | 41.03 | .91 |
| .982 | 94.56 | 92.86 | 49.89 | 63.89 | —14.00 | 38.64 | 11.25 | 50.69 | —.80 |
| 1.10 | 105.60 | 116.20 | 79.50 | 129.20 | —49.80 | 67.67 | 11.83 | 95.01 | —15.51 |
| 1.17 | 112.40 | 131.50 | 96.03 | 189.36 | —93.33 | 92.87 | 3.16 | 134.30 | —38.27 |

THOMSON–HOUSTON LAMP. 16 C.P. 75 VOLTS. (J)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .441 | 45.06 | 19.87 | .607 | .680 | —.073 | .763 | —.156 | .719 | —.112 |
| .488 | 49.28 | 24.05 | 1.17 | 1.20 | —.03 | 1.27 | —.10 | 1.24 | —.07 |
| .550 | 53.50 | 28.36 | 1.90 | 1.92 | —.02 | 2.02 | —.12 | 1.97 | —.07 |
| .562 | 56.32 | 31.65 | 2.66 | 2.67 | —.01 | 2.71 | —.05 | 2.69 | —.03 |
| .631 | 63.02 | 39.77 | 5.58 | 5.13 | .45 | 5.13 | .45 | 5.13 | .45 |
| .677 | 67.44 | 45.66 | 8.26 | 7.63 | .63 | 7.51 | .75 | 7.58 | .68 |
| .753 | 74.43 | 56.04 | 15.09 | 13.91 | 1.19 | 13.18 | 1.91 | 13.54 | 1.55 |
| .843 | 83.07 | 70.03 | 26.64 | 26.27 | .34 | 24.70 | 1.94 | 25.42 | 2.22 |
| .904 | 89.55 | 80.95 | 40.46 | 39.00 | 1.46 | 37.72 | 2.74 | 38.34 | 2.12 |
| .975 | 96.87 | 94.45 | 58.83 | 59.70 | —.87 | 58.93 | —.10 | 59.32 | —.49 |
| 1.120 | 110.20 | 123.40 | 113.69 | 130.50 | —16.81 | 122.58 | —8.89 | 126.41 | —12.72 |
| 1.220 | 125.30 | 152.90 | 138.50 | | | | | | |

THOMSON-HOUSTON LAMP. 16 C.P. 60 VOLTS. (K)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .349 | 30.64 | 10.70 | .323 | .308 | .015 | .413 | — .090 | .401 | — .078 |
| .428 | 37.31 | 15.97 | 1.175 | | | | | | |
| .490 | 42.72 | 20.93 | 2.770 | 2.484 | .286 | 2.505 | .265 | 2.503 | .267 |
| .572 | 49.99 | 28.59 | 6.520 | | | | | | |
| .640 | 56.04 | 35.87 | 11.93 | 10.77 | 1.16 | 11.02 | .91 | 10.90 | 1.03 |
| .718 | 63.13 | 45.33 | 22.16 | | | | | | |
| .797 | 70.68 | 56.33 | 39.22 | 35.80 | 3.42 | 38.95 | .27 | 37.33 | 1.89 |
| .872 | 76.82 | 64.99 | 53.84 | | | | | | |
| .931 | 83.92 | 78.13 | 67.50 | 83.91 | — 16.41 | 99.15 | — 31.65 | 91.21 | — 23.71 |

THOMSON–HOUSTON LAMP. 16 C.P. 60 VOLTS. (L)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .381 | 33.03 | 12.58 | .514 | .664 | —.150 | 2.85 | .229 | .418 | .096 |
| .420 | 36.55 | 15.35 | 1.04 | | | | | | |
| .461 | 40.41 | 18.63 | 1.85 | 1.86 | —.01 | 1.29 | .56 | 1.42 | .43 |
| .490 | 43.03 | 21.08 | 2.71 | | | | | | |
| .526 | 46.04 | 24.22 | 4.21 | 4.21 | 0.0 | 2.69 | 1.52 | 3.24 | .97 |
| .588 | 52.10 | 30.63 | 8.14 | | | | | | |
| .662 | 59.28 | 39.24 | 16.50 | 13.27 | 3.23 | 16.44 | .06 | 14.67 | 1.83 |
| .724 | 64.71 | 46.85 | 23.71 | | | | | | |
| .807 | 72.60 | 58.59 | 44.57 | 38.81 | 5.76 | 75.51 | —30.94 | 51.43 | —6.86 |
| .887 | 80.59 | 71.78 | 70.47 | | | | | | |
| .957 | 90.53 | 86.64 | 92.02 | 97.75 | —5.73 | 387.60 | —295.58 | 175.00 | —82.98 |

THOMSON–HOUSTON LAMP. 32 C.P. 52 VOLTS. (M)

| C. | P. D. | E. | C.P. OBSERVED. | C P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| 1.10 | 26.61 | 29.27 | .366 | | | | | | |
| 1.32 | 31 76 | 41.92 | 1.30 | 1.62 | —.32 | 1.28 | .02 | 1.34 | —.04 |
| 1.44 | 34.45 | 49.61 | 2.25 | | | | | | |
| 1.61 | 38.58 | 62.11 | 4.98 | 5.24 | —.26 | 3.53 | 1.45 | 4.30 | .68 |
| 1.84 | 43.79 | 80.57 | 10.55 | | | | | | |
| 1.98 | 47.73 | 94.11 | 17.03 | 17.93 | —.90 | 12.50 | 4.53 | 18.60 | —.67 |
| 2.14 | 51.48 | 110.20 | 26.10 | | | | | | |
| 2.31 | 55.84 | 129.00 | 40.04 | 44.76 | —4.72 | 31.78 | 8.26 | 37.71 | 2.33 |
| 2.46 | 59.42 | 146.20 | 56.97 | | | | | | |
| 2.67 | 64.63 | 172.60 | 86.21 | 105.80 | —19.59 | 75.63 | 11.58 | 89.52 | —3.31 |
| 2.83 | 68.15 | 192.90 | 109.60 | | | | | | |
| 2.98 | 72.17 | 215.10 | 139.20 | 203.17 | —63.97 | 145.82 | —6.62 | 172.10 | —32.90 |
| 3.01 | 71.89 | 216.40 | 117.50 | | | | | | |
| 3.10 | 74.29 | 230.30 | 132.00 | | | | | | |
| 3.27 | 78.71 | 257.40 | 155.10 | | | | | | |
| 3.38 | 81.66 | 276.00 | 155.10 | | | | | | |
| 3.76 | 93.07 | 349.90 | 191.20 | | | | | | |

THOMSON–HOUSTON LAMP. 32 C.P. 52 VOLTS. (N)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| 1.22 | 28.39 | 34.64 | .730 | | | | | | |
| 1.40 | 32.38 | 45.33 | 1.76 | 1.95 | —.19 | 2.32 | —.56 | 2.14 | —.38 |
| 1.55 | 35.85 | 55.57 | 3.60 | | | | | | |
| 1.71 | 39.42 | 67.40 | 6.35 | 5.80 | .55 | 6.23 | .12 | 6.04 | .31 |
| 1.81 | 41.90 | 75.84 | 9.08 | | | | | | |
| 1.94 | 45.06 | 87.42 | 13.52 | 11.64 | 1.88 | 12.21 | 1.41 | 11.94 | 1.58 |
| 2.10 | 48.72 | 102.30 | 20.34 | | | | | | |
| 2.30 | 53.56 | 123.20 | 35.01 | 29.54 | 5.47 | 29.11 | 5.90 | 29.34 | 5.67 |
| 2.47 | 57.87 | 142.90 | 48.00 | | | | | | |
| 2.64 | 62.23 | 164.30 | 72.62 | 62.81 | 9.81 | 61.93 | 10.69 | 62.36 | 10.26 |
| 2.82 | 66.54 | 187.60 | 95.05 | | | | | | |
| 3.08 | 72.37 | 222.90 | 151.30 | 145.91 | 5.39 | 131.96 | 19.34 | 138.68 | 12.62 |
| 3.49 | 82.84 | 287.10 | 246.70 | | | | | | |
| 3.79 | 90.31 | 342.30 | 307.50 | 453.78 | —146.28 | 402.63 | —95.13 | 426.68 | —119.18 |

THOMSON–HOUSTON LAMP. 20 C.P. 110 VOLTS. (0)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED (B) | DIFF | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .412 | 67.05 | 27.62 | .633 | | | | | | |
| .437 | 70.63 | 30.87 | .945 | 1.251 | —.306 | .886 | —.059 | 1.195 | —.250 |
| .469 | 75.55 | 35.43 | 1.57 | | | | | | |
| .509 | 82.09 | 41.78 | 2.79 | 2.63 | .16 | 2.62 | .17 | 2.62 | .17 |
| .563 | 89.41 | 50.34 | 5.07 | | | | | | |
| .632 | 96.87 | 61.22 | 8.70 | 7.45 | 1.25 | 6.68 | 2.02 | 7.07 | 1.63 |
| .660 | 101.90 | 67.24 | 12.38 | | | | | | |
| .727 | 111.50 | 81.07 | 20.31 | 14.55 | 5.76 | 14.80 | 5.51 | 14.68 | 5.63 |
| .784 | 117.80 | 92.39 | 28.38 | | | | | | |
| .883 | 131.40 | 116.00 | 39.76 | 37.08 | 2.68 | 37.50 | 2.26 | 37.25 | 2.51 |
| .959 | 140.40 | 134.60 | 56.04 | | | | | | |
| 1.065 | 152.30 | 162.20 | 84.37 | 91.39 | —7.02 | 86.46 | —2.09 | 89.00 | —5.63 |
| 1.140 | 162.10 | 185.30 | 107.40 | | | | | | |
| 1.230 | 173.30 | 213.90 | 128.70 | 185.50 | —56.80 | 179.56 | —50.86 | 182.77 | |
| 1.260 | 186.40 | 234.90 | 117.00 | | | | | | —54.07 |

THOMSON–HOUSTON LAMP. 20 C.P. 110 VOLTS. (P)

| C. | P. D. | E. | C.P. OBSERVED. | C.P. CALCULATED. (A) | DIFF. | C.P. CALCULATED. (B) | DIFF. | C.P. CALCULATED. (C) | DIFF. |
|---|---|---|---|---|---|---|---|---|---|
| .374 | 64.63 | 24.17 | .449 | .557 | —.108 | .323 | .126 | .549 | —.100 |
| .425 | 71.53 | 30.40 | 1.07 | | | | | | |
| .464 | 77.44 | 35.93 | 1.67 | 1.70 | —.03 | 1.25 | .42 | 1.71 | —.04 |
| .543 | 88.00 | 47.78 | 4.30 | | | | | | |
| .605 | 96.59 | 58.41 | 7.69 | 6.72 | .97 | 6.49 | 1.20 | 6.91 | .78 |
| .664 | 105.00 | 69.71 | 12.73 | | | | | | |
| .748 | 114.80 | 85.90 | 22.03 | 20.16 | 1.87 | 23.55 | —1.52 | 20.91 | 1.12 |
| .867 | 129.20 | 112.10 | 43.49 | | | | | | |
| .959 | 137.00 | 131.40 | 64.54 | 72.96 | —8.42 | 88.10 | —21.56 | 70.83 | —6.29 |
| 1.020 | 146.40 | 149.80 | 93.91 | | | | | | |
| 1.110 | 156.80 | 173.80 | 146.00 | 155.00 | —9.00 | 241.60 | —94.60 | 158.00 | —12.00 |

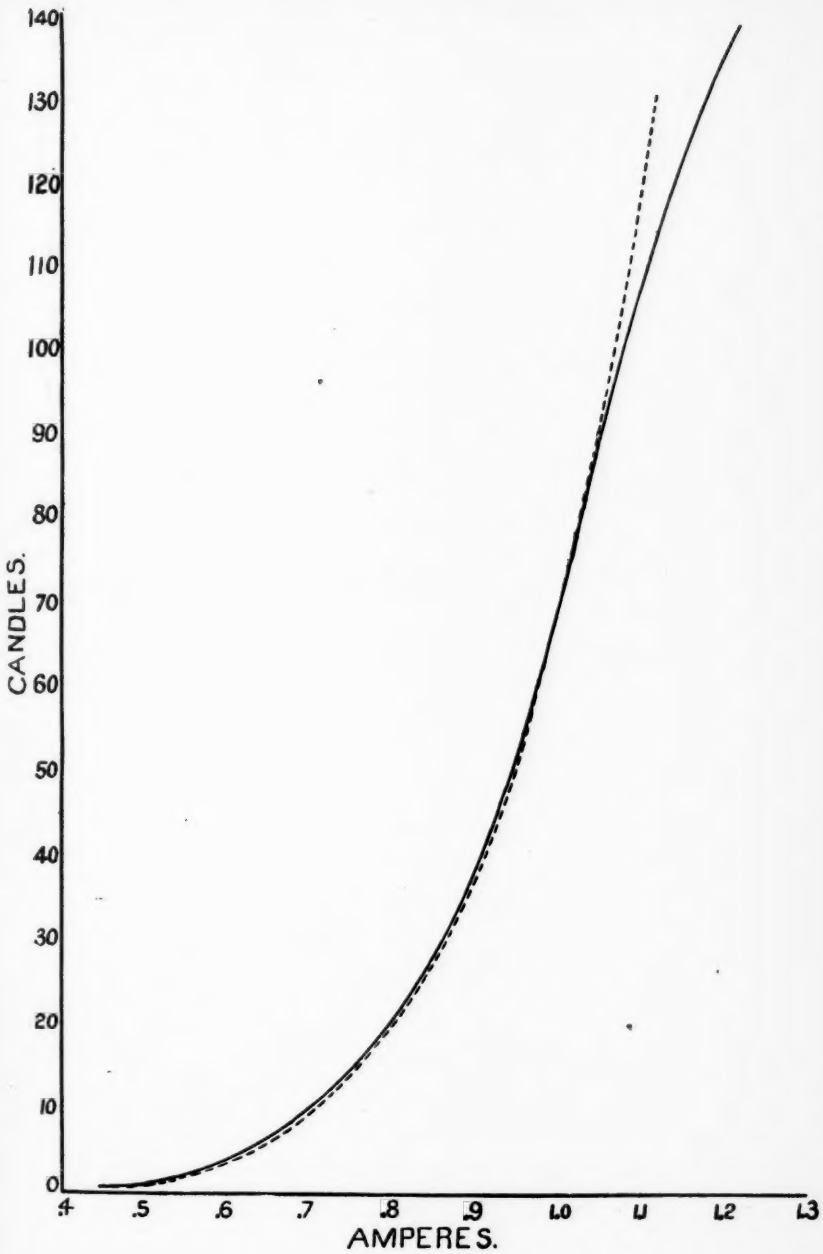
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Fig. 1.

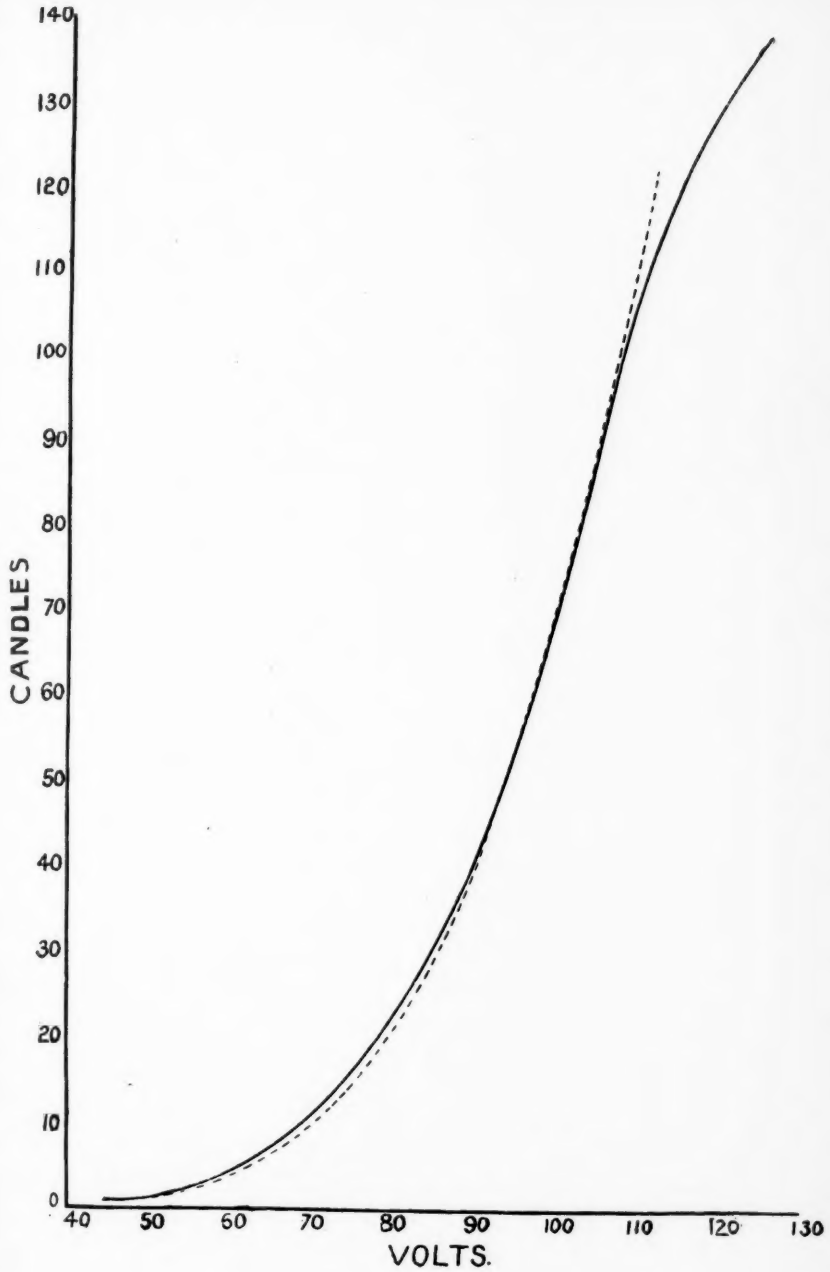
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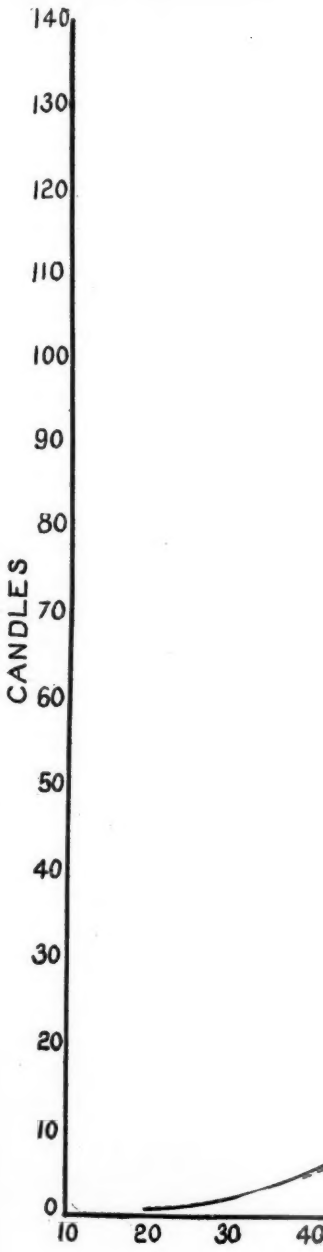
Fig. 2.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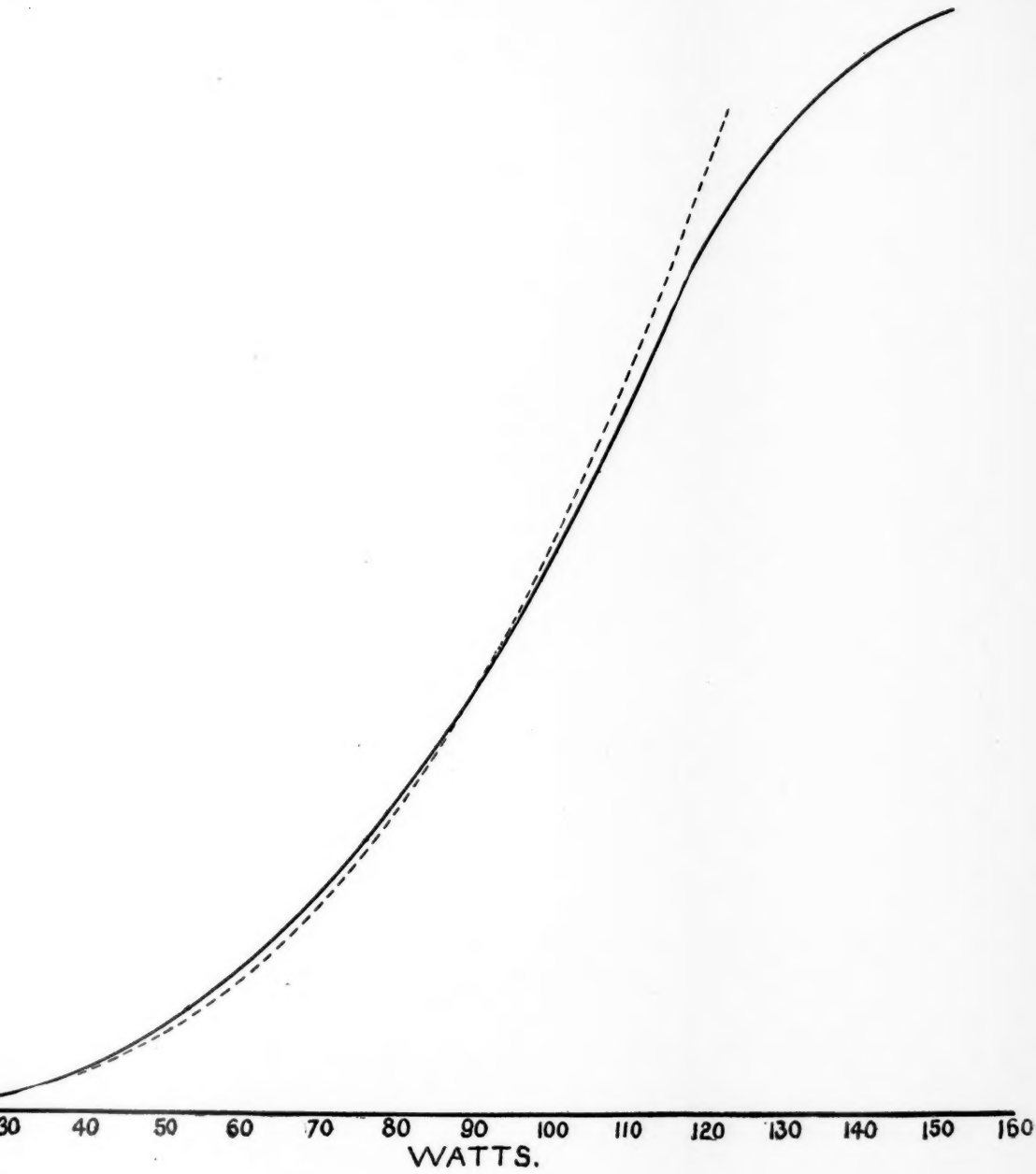



Fig. 3.

Although our general equations would be much enhanced in value if we could have employed a larger number of each kind of lamp in our investigations, there are, nevertheless, certain facts that are clearly evident from our results. The lamps at present used, like the earlier ones, increase in candle-power about as the fifth power of the current employed, and as the cube of the energy expended. It will also be seen that the candle-power increases about as the sixth power of the potential difference between the terminals of the lamp. The average value of the exponent of $x$, the candle-power for the current equations, is 5.3; for the energy equations, 2.9; and for the potential difference equations, 6.4.

To illustrate the agreement of the exponential equations with the observed relations between candle-power and current, potential difference, and energy expended, the curves shown in Figs. 1, 2, 3, were plotted for the Thomson-Houston 16 C.P., 75 volt lamp, indicated by the letter J in the tables. The equations used were the individual ones for that special lamp.

ROGERS LABORATORY OF PHYSICS.
*June, 1890.*

# THE GEOMETRICAL ISOMERISM OF THE CHLORCINNAMIC ACIDS.[1]

By S. P. MULLIKEN, Ph.D.

Previous to the recent publication of A. Michael on the chlorcinnamic acids, which appeared in the *Journal für praktische Chemie*, **40**, 63, shortly before the completion of the author's work on the same subject in the laboratory of Wislicenus, our knowledge of the isomeric relations of these acids was extremely incomplete and confused. The two acids which should properly be designated as *α* chlorcinnamic acid and *α* chlorisocinnamic acid were first obtained by Jutz[2] in 1882, by treating cinnamic acid dichloride with alchoholic potash. Jutz adopted the same nomenclature that had been employed by Glaser[3] for the corresponding bromcinnamic acids, and called the acid with the melting point 142° *α* chlorcinnamic acid, and that with the melting point 114° *β* chlorcinnamic acid. The correctness of this nomenclature in the case of the *α* acid was soon after shown by Plöchl,[4] who succeeded in preparing it by Perkin's reaction from benzaldehyde and sodium chloracetate. According to Plöchl, the so-called *β* acid forms scarcely any of its isomer on being repeatedly distilled, or even after being heated with hydriodic acid — a behavior which is somewhat surprising when the easy transformation of the *β* bromcinnamic acid of Glaser into his *α* bromcinnamic acid is recalled. Still another proof that the chlorcinnamic acid of higher melting point has its Cl atom in the *α* position, is given by Forrer,[5] who obtained a chlorcinnamic acid of melting point 138° –

[1] From an "Inaugural Dissertation" "Ueber die Konstitution der Chlorzimmtsäuren," Leipzig, 1890.

[2] Jutz, Berichte der deutschen chemischen Gesellschaft, **15**, 788.

[3] Glaser, Liebig's Annalen, **143**, 330.

[4] Plöchl, Berichte der deutschen chemischen Gesellschaft, **15**, 1945.

[5] Forrer, Berichte der deutschen chemischen Gesellschaft, **16**, 854.

139° by withdrawing one molecule of water from phenylchlorlactic acid ($C_6H_5CH.OH.CHCl.COOH$).

About two years later Perkin[1] obtained the first real β chlorcinnamic acid by treating benzoylacetic ether with phosphorus-pentachloride, and decomposing the product of the reaction with water. Perkin, however, erroneously believed his acid to be identical with the α acid of Jutz, because both exactly coincided in their melting points. Finally, Michael, in the article already mentioned, describes the preparation of two β chlorcinnamic acids by allowing hydrochloric acid and phenylpropiolic acid in glacial acetic acid solution to react on each other in sealed tubes for about a week at the ordinary temperature. One of these isomers melted at 132.5°; the other at 142°. Michael rightly considers that both are to be regarded as having their Cl atom in the β position; or, in other words, that they are geometrical isomers standing in a similar relationship to each other as the two isomers discovered by Jutz. The experiments of the author confirm the conclusions of Michael, and were further intended to show, by employment of methods already used by Wislicenus, which stereochemical formulæ probably represent the constitution of the several isomers.

The two α acids were prepared by the method of Jutz, according to the reactions: —

$$C_6H_5CH.\ CH.\ COOH + Cl_2 = C_6H_5CHCl.\ CHCl.\ COOH, \text{ and}$$
$$C_6H_5CHCl.\ CHCl.\ COOH + 2KOH = C_6H_5CH : CCl.\ COOK + KCl + H_2O.$$

The formation of two geometrical isomers from cinnamic acid dichloride may be ascribed to a series of reactions analogous to that which occurs in the case of the formation of the α chlorcrotonic acids from isocrotonic acid dichloride (Wislicenus, Liebig's Annalen, **248**, 286). The isomeric acids were separated by taking advantage of the great difference in the solubility of their potassium salts in strong alcohol, the salt of the acid of lower melting point requiring only 3.58 parts of absolute alcohol for solution at 20°, while the salt of the acid with higher melting point requires 638 parts of this solvent at the same temperature. The pure acids were found to have their respective melting points at 110.5° and 139° — an observation which agrees quite closely with those made by Forrer and Michael, and indicates that the melting points as determined by Jutz were both too high.

[1] Perkin, Journal of Chemical Society, **47**, 256.

In studying the constitutions of these isomers, it had first to be shown that they were actually geometrical and not structural isomers. This could be accomplished by examining their behavior on heating; for, like other double-bonded organic acids which exist in two geometrically isomeric modifications, one of the *a* chlorcinnamic acids contains its constituent atoms and radicals grouped in an arrangement of more stable equilibrium than the other, so that the simple application of heat to the less stable compound is sufficient to convert it into the more stable form. The experiments made to determine the effects of heat were carried out by heating weighed quantities of the pure acids, enclosed in sealed tubes, in a thermostat, then exactly neutralizing the alcoholic solutions of the acids taken from the tubes with an alcoholic solution of potash, and separating, drying and weighing the difficultly and easily soluble potassium salts thus formed. The following tabulation of the results obtained shows that the acid of melting point 139°, even after long heating at 180°, remained quite unchanged; while of the acid melting at 110.5°, more than three fourths were converted into its more stable isomer.

| | Temperature. | Duration of heating. | Unchanged acid. | Acid converted into its isomer. |
|---|---|---|---|---|
| Acid m. pt., 110.5° | 160° | 5 hours. | —— per cent. | 53 per cent. |
| | 176° | 5 " | —— " | 73 " |
| | 178° | 10 " | —— " | 90 " |
| Acid m. pt., 139° | 140° | 5 " | 100.0 " | —— " |
| | 160° | 5 " | 99.2 " | —— " |
| | 180° | 6 " | 99.5 " | —— " |

The principle that HCl is more readily withdrawn by potash from compounds containing H and Cl attached to two carbon atoms connected by a double bond, when the H and Cl atoms are in plane-symmetrical positions to one another, than when they occupy axially symmetrical positions, has been assumed and frequently employed by Wislicenus in explaining the constitution of geometrical isomers. Applying this method to the *a* chlorcinnamic acids, it is evidently to be expected that of the two configurations,

$$\underset{\text{Cl}-\text{C}-\text{COOH}}{\overset{\text{H}-\text{C}-\text{C}_6\text{H}_5}{\overset{\|}{\phantom{\text{C}}}}} \quad \text{(I)} \qquad \text{and} \qquad \underset{\text{Cl}-\text{C}-\text{COOH},}{\overset{\text{C}_6\text{H}_5-\text{C}-\text{H}}{\overset{\|}{\phantom{\text{C}}}}} \quad \text{(II)}$$

(I) would lose HCl and form the triple bonded phenylpropiolic acid $\overset{\text{C}-\text{C}_6\text{H}_5}{\overset{\|\|}{\text{C}-\text{COOH}}}$ much more readily than (II).

Aqueous solutions of the potassium salts of both acids were prepared by dissolving in each case 0.5 gm. (1 mol.) of the acid in 10 cc. of water containing 2½ mol. of KOH. These tubes were immersed side by side in a bath of boiling water, and heated, in one experiment for ten, and in a second for thirty minutes. The percentage of chlorine withdrawn as potassium chloride was then gravimetrically determined for each tube, and from these results the percentage of decomposed acid calculated.

| Acid | Duration of heating. | Per cent of acid decomposed. |
|---|---|---|
| m. pt., 139° | 10 minutes. | 6.62 per cent. |
| " 110.5° | 10 " | 0.99 " |
| " 139° | 30 " | 39.02 " |
| " 110.5° | 30 " | 2.41 " |

From the above it will be seen that the *a* chlorcinnamic acid melting at 139° should have the constitution expressed by (I), while its isomer, melting at 110.5°, should be represented by (II).

In preparing the *β* chlorcinnamic acids, resort was made to two methods. The first consisted in heating phenylpropiolic acid in sealed tubes with an excess of fuming hydrochloric acid for several hours, to a temperature between eighty and ninety degrees.

$$\begin{matrix} C_6H_5-C \\ \| \\ HOOC-C \end{matrix} + HCl = \begin{matrix} C_6H_5-C-Cl \\ | \\ HOOC-C-H \end{matrix}$$

If a much higher temperature be used, the chlorcinnamic acids formed are decomposed, giving rise to acetophenon and carbonic acid. At the ordinary temperature the addition of hydrochloric acid does not take place. The two geometrical isomers produced by the reaction are separated by means of their potassium salts. The potassium salt of the acid melting at 132° is soluble in 1.2 parts of absolute alcohol at 20°; while the potassium salt of the acid melting at 143° dissolves in 386 parts of alcohol at the same temperature. The yield of the acid with the higher melting point was about one and a half times as large as that of its isomer. When it is desired to obtain this acid of *higher melting point only*, Perkin's method is to be recommended, as benzoylacetic ether, at the present time, is more accessible than phenylpropiolic acid. The reactions that take place are: —

$$C_6H_5.CO.CH_2.COOC_2H_5 + 2PCl_5 = C_6H_5.CCl_2.CH_2.COCl + C_2H_5Cl + 2POCl_3,$$
$$\text{and, } C_6H_5.CCl_2.CH_2.COCl + H_2O = HCl + C_6H_5.CCl : CH.COOH.$$

The fact that these two chlorcinnamic acids are geometrical and not structural isomers, was shown by converting one into the other by the agency of heat, in the manner described in speaking of the *a* chlorcinnamic acids. It was found, for instance, after heating a portion of the acid melting at 132° for five hours at 170°, that 76% of the acid had been changed into its isomer melting at 143°. It was, on the contrary, found impossible to detect any of the lower melting acid in the acid of higher melting point after a similar treatment. In this connection it is deserving of remark, that, while the *a* chlorcinnamic acids may be heated for hours at 170° without showing any sign of decomposition, the *β* compounds are much less stable, and after heating are always mixed with more or less tarry matter.

The *β* chlorcinnamic acids can be easily reduced by mild reducing agents; but, unfortunately, a molecular rearrangement appears to accompany the reduction, so that common cinnamic acid was always the only product that could be isolated. When we consider the remarkable tendency, which, as Liebermann[1] has shown, the isocinnamic acid possesses to change in its solutions into the ordinary cinnamic acid, this observation becomes hardly surprising.

As a means of directly proving the *β* position of the Cl atom in the chlorcinnamic acid of melting point 142°, a small quantity of the methyl ether was prepared from its silver salt and methyl iodide. The alcoholic solution of this ether, which formed well developed colorless crystals melting at 25°, was treated cautiously with somewhat more than the calculated quantity of a solution of sodium ethylate. The reaction,

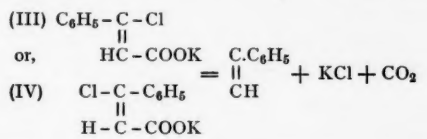
$$C_6H_5CCl : CH.\,COOC_2H_5 + C_2H_5ONa = NaCl + C_6H_5COC_2H_5 : CH.\,COOCH_3,$$

which was allowed to take place in the cold, yielded an oil boiling, under a pressure of 77 mm., between 209° and 211°. Analysis showed this oil to have very nearly the percentage composition required for the methyl ether of *β* ethoxylcinnamic acid. When left for several hours in contact with sulphuric acid containing water, at the temperature of the laboratory, the solution of the oil in dilute alcohol gave a strong violet-red coloration on being mixed with ferric chloride solution. The benzoylacetic ether, to which this coloration was due, was, however, destroyed by continued action of

[1] Liebermann, Berichte der deutschen chemischen Gesellschaft, 23, 144.

the sulphuric acid, so that the oil finally consisted largely of acetophenon, as was proved by converting a portion of it into the characteristic compound with phenylhydrazine. The phenylhydrazine compound melted at 105°, and contained exactly the percentage of nitrogen required by the formula $C_{14}H_{14}N_2$.

For the purpose of determining the stereochemical formulæ of the $\beta$ chlorcinnamic acids, it was found practicable to employ, besides determining the rate at which HCl is split off from the two isomers by potash, another method of the same type, based on the fact, that, like the alkali salts of other organic acids having a Cl atom in the $\beta$ position, the potassium salts of the $\beta$ chlorcinnamic acids decompose on being heated in aqueous solution into an unsaturated hydrocarbon, alkaline chloride, and carbon dioxide:—



Now it is reasonable to suppose that the compound (III) would undergo such a splitting more readily than (IV), in which the groups to be removed lie on opposite sides of the central axis of the system. The experiments were all made by heating 0.5 gm. of the pure potassium salts, mixed with 2.5 cc. of water, in closed tubes, in a thermostat. The products were always phenylacetylene boiling at 141° – 142°, potassium chloride and carbon dioxide. Silver nitrate precipitated the phenylacetylene from its solution in dilute alcohol as phenylacetylene-silver ($C_6H_5C{\equiv}CAg$)[1], whose purity was established by a silver determination.

In the quantitative experiments made to ascertain the rate at which the decomposition of the two potassium salts progressed, the chlorine in the potassium chloride formed by the reaction, was determined by precipitation with silver nitrate.

| K salt of acid melting at | Duration of heating. | Temperature. | Per cent. of K salt decomposed. |
|---|---|---|---|
| 143° | 2½ hours. | 120° | 15.8 per cent. |
| 132.5° | 2½ " | 120° | 76.8 " |
| 143° | 5 " | 127° | 29.9 " |
| 132.5° | 5 " | 127° | 100.0 " |

[1] Glaser, by a singular mistake, assigns to phenylacetylene-silver the formula ($C_6H_5C{\equiv}CAg)_2$ $Ag_2O$.

The $\beta$ chlor-cinnamic acid melting at 132°, accordingly, corresponds to configuration (III), and the acid of melting point 143° to configuration (IV).

The experiments next made were to confirm the above results by heating the acids with an excess of potash solution, just as was done in the investigation of the $\alpha$ acids. The salt represented by configuration (III), according to the theory, should split off H and Cl more slowly under such treatment than the salt of configuration (IV); and, as the acid of melting point 143° was found to be the more reactive of the two isomers, the probability that the formula $\begin{matrix} Cl\text{-}C\text{-}C_6H_5 \\ \| \\ H\text{-}C\text{-}COOH \end{matrix}$ is actually the one representing this acid, thus receives fresh support. The numerical results obtained were the following: —

| Acid | Duration of heating. | Temperature of both. | Per cent. of acid decomposed. |
|---|---|---|---|
| m. pt., 143° | 10 minutes. | 100° | 100.0 per cent. |
| " 132.5° | 10 " | 100° | 56.5 " |
| " 143° | 30 " | 100° | 100.0 " |
| " 132.5° | 30 " | 100° | 80.5 " |

Finally, after having seen how an unusually complete series of reactions all agree in indicating certain definite stereochemical formulæ for each of the chlorcinnamic acids, it remains to be added, that, striking as the cumulative evidence furnished by the agreement of these typical Wislicenian methods is, it is yet hardly sufficient to place the conclusions arrived at in a position secure against attack. Preliminary measurements of the electrical conductivity of the $\alpha$ acids by the author, gave affinity coefficients,[1] which at present seem irreconcilable with the stereochemical constitutions above assigned to these substances, although they completely confirm the conclusions reached regarding the ordinary structural symbols. Similar measurements of the $\beta$ acids showed much smaller values for K than those possessed by the $\alpha$ acids; but the difference between the conductivity of the two geometrical isomers themselves was too slight to permit of safely drawing conclusions about their geometrical structure.

A like disagreement between the results obtained by the employ-

[1] For $\alpha$ acid, m. pt. 110.5°, K = 1.07. For $\alpha$ acid, m. pt. 139°, K = .097. For $\beta$ acids, K = .0275 (approximately).

ment of the chemical and the electrical methods has just been brought to light by J. Mendelsohn (Dissertation, Leipzig, 1891), in a study of the $\beta$ bromcinnamic acids; while the $\beta$ chlorcrotonic acids furnish still another riddle of the same kind. Do these contradictions show the unfitness of either of these methods for use in solving such problems of stereochemistry? If not, the customary manner of interpreting the data furnished by at least one of them must be at fault. The question is one whose importance will be recognized by all who are interested in stereochemical matters. Its discussion, however, cannot be attempted in this place.

BRYN MAWR COLLEGE,
*September*, 1891.

# *THE ORIGIN OF DEATH.*

By Edward G. Gardiner, Ph.D.

Among the most brilliant of modern biologists is to be reckoned Prof. Augustus Weismann, of Freiburg. His numerous contributions to science place him in the rank of those whose words are never without interest and value to the naturalist; but, besides his publications, which give record of long and laborious experiments and observation, he has added a series of essays of profound interest, not only to the specialist, but to every mind which takes pleasure in scientific speculation.

These essays are devoted to the discussion of a new theory of heredity; but, besides this, he advances views which to many must seem startling, viz.: that death, in the sense in which we know it, did not always exist, but is something which has been acquired by the higher animals as they were evolved from the lower; and further, that individuals of a large group of animals living today are potentially immortal.

In one of his earlier essays he points out that the manner of reproduction among the Protozoa is such that death does not normally occur in this group; for the animal reproduces by merely dividing itself into halves. Thus an adult animal ceases to exist as such, by becoming two animals instead of one. It does not die during this process, for there is no corpse; but the whole animal, as such, has completely disappeared, and in its place we find two individuals so similar that it is impossible to regard them as parent and offspring. Indeed, they cannot be parent and offspring, for they are of the same generation; it is more natural to call them twins. They are both young animals, for they increase in size; and when adult, each of them ceases to exist by dividing itself into two new young ones, and so on indefinitely.

Hence it would appear that the life history of such an animal may be divided into two periods — youth and adult life. There is no old age; there is no death. Clearly, then, since these forms do not die, they may be said to be potentially immortal. The living matter of which they are composed passes over without break into a younger generation, and in it, life is continued. These facts have been long known, and earlier investigators have pointed out the potential immortality which this mode of reproduction implies; but Weismann was the first to develop this knowledge into a scientific theory which may throw light on other facts.

When Weismann calls these animals immortal, he draws a proper distinction between the terms immortal and eternal. Eternity reaches back into the past, as well as out into the future. With eternity he has nothing to do. Neither does he use immortality in the sense in which it is used in theology — as applied to something which can never die, but must exist through all future time. His claim is not that the life of a Protozoön is such that it must under any circumstances exist forever, but that it will exist as long as proper physical conditions exist; that death is not inherent in life.

He compares the life cycle of a Protozoön to the circulation of water, which evaporates, gathers in clouds, and falls to the earth, only to evaporate again. And there is no inherent cause in the physical and chemical properties of water which will bring this cycle to an end. As long as the present physical conditions exist, the cycle must continue. So it is, he claims, with the life cycle of a Protozoön; *i.e.*, division, growth by assimilation, division again — and so on without end; there being no inherent cause in the constitution of the protoplasm which will cause it to fall short of its cycle and physiologically decline in fertility and vigor. He does not mean that such unicellular forms cannot be starved to death, crushed out of existence, devoured, or killed by disease. These are rather accidental than natural deaths. Neither would he claim that in no case have individuals by insufficient nutrition or unfavorable surroundings acquired the seeds of death, so that their race has been limited, and finally become extinct. This again is accidental rather than natural death. He claims only that since life has existed in these forms, it has passed unbroken from one generation to another down to today. The material of which the individual is made may change, but in all cases it is animated by the same life.

Now no one doubts that the Metazoa have at some time in the remote past been evolved from such potentially immortal Protozoa. But the life of all of the Metazoa may be divided into *three* periods, — youth, adult life, and old age, during which latter there is clearly a physiological decline in vigor, which is terminated normally by death.

Old age and death then would appear to be something which have been acquired with the development of the Metazoa from the Protozoa. Exactly for what purpose, and how, death has been instituted, are questions which Weismann endeavors to answer.

But first let us compare the life history of a Metazoön with that of a Protozoön, and see whether there is anything in the Metazoa which is comparable to Protozoön immortality. All Metazoa start their individual lives from an ovum, which is a single cell, and may well be compared to a Protozoön. After fertilization this cell or ovum divides into two, then into four, then into eight cells, and so on, thus giving rise to a very large number of cells, which, as development progresses, differentiate to form the tissues and organs of the embryo. Now of these cells in the embryo Weismann distinguishes two different kinds; viz., the germ cells, which lie in the generative glands of the animal, and the somatic cells, which form all other organs and the body itself. During early youth the germ cells remain dormant. When, however, adult life is reached, they develop, and under proper conditions, such as fertilization, etc., each one is capable of producing a new organism, with germ cells and body, while the body itself grows old and dies. The germ cells of the second generation do not die, but produce a third, and the third a fourth generation, and so on. The body of each of these generations must grow old and die, but the germ cells themselves, if allowed the proper physical surroundings, do not. They go on germinating, and so produce generation after generation.

Hence it would appear that the germ cells of the higher organisms are exactly parallel to the entire body of the lower forms, and like them are endowed with potential immortality, and that this immortality has never been broken by death since life first existed on this earth. In other words a Metazoön equals a colony of Protozoa plus a perishable body.

Death, then, is something secondary; an adaptation which has been acquired during the evolution of the mortal, from the lowly immortal forms.

Weismann suggests that this adaptation of death has been brought about in the following manner, by what he terms *panmixia*, or the cessation of natural selection. It is generally admitted that congenital variation in the size and form of every organ or part occurs constantly, and further that such variation is liable to be inherited; also that species are formed and maintained by natural selection preserving the most favorable variations. For instance, the large and powerful wings of wild ducks and geese are an absolute necessity to them, not only to escape enemies but to migrate from the sub-tropics to the arctic zone as the change of climate and scarcity of food necessitate. With weak wings, a wild duck or goose would have but poor chance of competing with its companions in the stern struggle for existence which is a part of its life. In the stormy northern hemisphere in which most of these birds breed, strong powers of flight are of vast advantage, and when the time for migration comes, an absolute necessity.

Now if some of the young of these birds vary even a little from the parental type, and have even stronger wings than the average, so much the more fortunate they; if, on the other hand, the wings are below the average, there is just so much less chance of their accomplishing the migration safely and returning another year to breed and transmit to their offspring their short-winged peculiarity. In these birds it would seem that natural selection compels strong powers of flight, and that the strong wings which characterize them are maintained by a survival of the fittest. This is a well-known law.

Now without doubt the domestic ducks and geese are descended from wild forms; yet they fly but poorly. Indeed, actual comparison shows that the wing bones are smaller in the domestic than in wild ducks. But in domestic ducks the power of flight is but little used. It is of no advantage to it to fly far and fast, and hence in these forms, the young with small wings would be as apt to survive and transmit their individual variation as would the long-winged ones, and as a consequence of this free interbreeding of the long and the short winged, the general average of length of wing would deteriorate. In other words, natural selection would cease to compel long wings, and *panmixia*, or the "mingling of all," would allow them to degenerate. There are several kinds of wild bird — the dodo, penguin, apteryx, ostrich, — incapable of flight, and all doubtless de-

scended from birds with functional wings. This may be accounted for if we can suppose that gradually the ancestors of these forms, by change of habit, climate, or surrounding conditions, were able to obtain their food with but slight use of the wings. Then the survival of only the strong of wing would cease, and *panmixia* would cause the wings to degenerate.

Without doubt the eyesight of animals which live in the light of day is maintained in its perfection by the action of natural selection. Take, for example, the birds of prey, such as the eagle or vulture, which have exceedingly keen sight, by means of which they detect their food at great distances. A near-sighted vulture would have but poor chance of competing successfully with its more fortunate companions. Another example may be found among savage races of men. It is often asserted that the North American Indians have eyesight keener than that of most white men. To the Indian this sense is of as much importance as to the vulture or eagle, for like them, he is dependent on the chase for his livelihood. A myopic or weak-sighted Indian could rarely survive to transmit his weakness to the race. In both these cases the keen sight has been produced by a survival of only the fittest; and if this natural selection were removed, the result would be a reduction in the power of the organ in question. We are, of course, descended from keen-sighted savages, but civilization has introduced other means of support, in which the myopic individual stands on equal terms with the man of normally, or even abnormally, good sight. Here again *panmixia* has caused an organ to degenerate.

Similar cases are to be found among animals which live in subterranean caves where total darkness prevails. Some of these caves have existed since the Pliocene period, and it is probable that their present inhabitants, insects, crustacea, amphibia, and fish, have lived and bred there for thousands of generations. Many of these are blind, having but rudimentary eyes. Some are also colorless. Now to animals living in the light of day, color is either protective, or of some advantage; therefore it is maintained by natural selection. But if congenital variation should produce animals with less vivid hue, these would, of course, survive in total darkness as well as their more brilliant brethren; and by breeding with them, the colors of all would gradually be reduced.

And so with their eyesight. What advantage is eyesight in total darkness? It is interesting to note how in these caves natural selection has been enlarging and developing organs which are of use in darkness, even while in the same species *panmixia* has been reducing those which are useless. In the Mammoth Cave there is a blind, colorless, and wingless grasshopper. Eyesight, color, and wings have been aborted by *panmixia;* but it has singularly long and delicate antennæ, which serve as feelers, and which are not nearly so conspicuous in forms living in the light of day. It would seem then that natural selection maintains only what is of advantage to an animal, and when it neglects an organ, that organ tends to degenerate by the action of *panmixia;* and these laws apply to the physiological functions of organs, as well as to the structure of the organs themselves.

Is immortality essential to the Protozoön? Weismann claims that it is, for the whole body is the germ-cell by which the race is perpetuated; hence, if the body should lose its immortality, the race would become extinct. Immortality then is retained by natural selection.

Now among the Metazoa the case is quite different. In these forms immortality is only essential to the germ cells. The body is merely the bearer and protector of these precious germs, and immortality is in no sense essential to it; hence it has not been maintained by natural selection, but has disappeared through *panmixia.*

Weismann suggests that the Metazoa, with their immortal germ and perishable body, have been evolved from the wholly immortal unicellular form something as follows: Many Protozoa form cluster-like colonies. In such groups those on the outer side must obtain food more readily than those in the center; hence the colony would become gradually differentiated into feeding cells on the outer side and reproductive cells on the inner side, the feeding cells supplying the reproductive cells with nutriment just as the digestive cells of Hydractinia supply the rest of the colony. The cells that are thus supplied with food would have no use for mouth, cilia, etc.; hence they would lose them, but might retain their reproductive powers. If these central cells retained their immortality, there would be no necessity for the feeding cells doing so also; and if natural selection does not compel the retention of a physiological character, it degenerates, just as a useless organ degenerates.

Certain of the lower forms, such as Volvox, suggest this manner of evolution of the Metazoa from the Protozoa. Volvox is a hollow sphere of cells, each of which is provided with a couple of long flagella, by means of which the colony swims. Some of these cells pass to the center of the sphere, and there undergo certain changes in form, becoming, in fact, the reproductive cells of the colony. When they are ripe, the rest of the colony withers up and dies. Hence we find in Volvox the first approach to a differentiation into germ and somatic cells.

Since Weismann made this startling assertion, that death is not an attribute of all living organisms, much opposing evidence has been brought forward. Most prominent and recent among his opponents is E. Maupas, of Algiers, who, after extensive study of some of the Infusoria, asserts that degeneration and death occur as normally among the Protozoa as among the Metazoa. Before entering on his experiments, Maupas first determined very carefully the habits of the different species which he chose for study. He found out the temperature to which they were best adapted, and the kind of food on which they throve best. Then he took a single individual and isolated it on a glass slide, on which it could be studied. This slide was kept over a dish of water, in a warm, damp chamber in which the air was so thoroughly saturated with moisture that evaporation was reduced to a minimum. During its confinement the animal was fed on its favorite food, and in every particular what seemed to be the most suitable conditions were maintained. He found that at the end of seven days there were no less than 935 Infusoria in his culture. One of these 935 he isolated and kept as he had the first. In four days this single one had increased to 230. One of these was isolated in the same way, and this process of isolating and confining one individual of each brood was continued through a large number of generations. He shows the rapidity of increase to be something almost incredible. Calculations show that in six and a half days a single Stylonichia might produce by fission a mass of protoplasm which should weigh one kilogram, and that in thirty days the number of kilograms would be represented by 1 with forty-four zeros, or a mass of protoplasm a million times larger than the volume of the sun!

Cultures were made of no less than twenty different species of Infusoria, and were maintained during periods of time varying in

different cases from two weeks to between four and five months. He found that after from fifty to one hundred generations had been produced by fission, there was clear evidence of a physiological decline, which seemed to indicate the approaching extinction of the culture. He withdrew some of the Infusoria from the culture and allowed them to mix with others of a different origin. With these they conjugated, and their full vigor seemed restored. If, on the other hand, they conjugated among themselves, observation showed that decline was so far advanced that the culture was doomed.

Soon the animals produced by fission were smaller — often being less than half the normal size. At the same time what might be called pathological changes began to appear. The cilia were absent on parts of the body, and the Infusoria seemed weaker and less able to digest food. In some species the micro-nucleus underwent changes, finally falling to pieces — a phenomenon which not unfrequently occurs in the cells of the Metazoa when the tissue is undergoing degeneration. Also the macro-nucleus was found to undergo marked pathological changes, finally breaking down and disappearing.

When this degeneration, which Maupas calls senile degeneration, reaches its maximum, nutrition becomes impossible, and death follows. Thus it would appear that the life of these animals is cyclic. During the period of reproduction, which is the adult life of the animal, a sort of physiological decline takes place, and this decline can be repaired only by conjugation.

Now if, during these experiments, the animals have not been injured or poisoned, it would seem at the first glance that Maupas had proved that among the Infusoria death may occur normally; and on the strength of his experiments he holds up Weismann's theory to ridicule. This is evidently unfair, for although he has shown that Weismann was wrong in ascribing immortality to the Infusoria, yet there are many well-known unicellular forms in which neither a physiological decline nor a process of rejuvenation has been observed. The Bacteria, the Cyanophyceæ, and Yeast, increase by budding, spore-building, and fission; conjugation does not occur, and unless their life-history is much less well known than bacteriologists and botanists think, these forms are potentially immortal. The Infusoria, on the other hand, are the highest and most differentiated of unicellular forms. They have organs of locomotion, mouth, pharynx, some sort of excretory apparatus, myophanes (muscle-like structures), trichocysts,

etc.; while in the lowest organisms none of these organs are to be found. Further, the Infusoria have a macro-nucleus which Maupas shows is vegetative in its function, and a micro-nucleus which is generative. If the macro-nucleus is lost, nutrition fails; and if the micro-nucleus is lost, conjugation is impossible. In many of the lower Protozoa no such differentiation has been observed, and there is merely one nucleus, which is surrounded by a mass of protoplasm.

In a recent article Bütschli maintains that in the Bacteria the whole body is the nucleus, and that the surrounding mass of protoplasm, such as characterizes the Rhizopods, is absent. Between the Bacteria and Infusoria there is a wide gap in the zoölogical scale. Is it not possible that as the Infusoria were evolved from lower and simpler forms, the process of conjugation was first acquired? that when, in the cycle of metabolic changes, the protoplasm fell short of the point from which it started and to which it should return, this deficiency was made up by foreign substance obtained from an individual of different origin, and therefore of different material? Those of the primitive forms which retained their original immortality have left lineal descendants which we know today as Bacteria. Those which in a measure lost that power have either become extinct, or else acquired a habit of rejuvenescence by conjugation. In other words, those to which it was an advantage to retain their immortality have retained it, and those which varied in such a manner that immortality could be advantageously replaced by rejuvenescence have, by the action of natural selection, undergone this modification. If this is so, Weismann's error is not in claiming that death was an adaptation, but in asserting that all unicellular forms are immortal.

Weismann, however, is not ready to admit this. He claims that conjugation is a necessary condition of the animal's life, just as fertilization is a necessary condition for the survival of an ovum, and if conjugation is denied, the death in consequence is accidental and not natural; further, that the fact that conjugation is necessary does not imply that the protoplasm is not potentially immortal. He seems, however, to overlook the fact that a certain physiological decline has taken place, and that if there is any physiological decline the cycle of life is incomplete — therefore the seeds of death must exist inherent within the life of the animal. It is, then, for the present, impossible to speak of the Infusoria as potentially immor-

tal, and to claim that that portion of the Metazoa which undergoes physiological decline has no equivalent in these forms.

Still another and earlier opponent of Weismann has urged serious objections to this theory of the origin of death. Professor Charles S. Minot was the first to maintain — and many have taken up his suggestion — that Weismann is fundamentally wrong in comparing the life history of a Metazoön, which is a complex colony of cells, with that of a Protozoön, which is a single cell. Minot urges that an individual Metazoön is comparable to a colony of Protozoa, not to a single cell. If this be so, then the death of a Metazoön (a colony of cells) has its only homologue in the degeneration and death of a culture of Protozoa. The Metazoön colony is the product of a single germ cell, as is also the whole culture of Infusoria.

This comparison seems safe between the Metazoa and those forms of Protozoa which conjugate, and in which senile degeneration occurs. But how is it when we bring those which do not conjugate under consideration? If this view be correct, then a single Metazoön is equivalent to all of a species of Bacterium which may arise through generations of fission. As far as our knowledge goes, these Bacteria are immortal, and their numbers almost infinite. We know, on the other hand, that nothing but the germ cell of the Metazoa possesses this immortality and vast power of reproduction.

But to return to Weismann's views. If death is not something which is inherent in living matter, but which is acquired, how is it that the length of life differs so markedly in different species? Weismann answers that the age which an animal may attain has been determined by natural selection, and also that the power of reproduction and length of life are correlated. In order to understand this view it is necessary to compare the length of life with the reproductive powers of different animals. Birds, as a rule, live to a surprisingly great age. Even the smallest singing birds live for ten years; while some live for twelve, or even eighteen years. A partridge lives from twenty to twenty-five years. A pair of eider ducks was observed nesting in the same place for twenty years, and it is believed that these birds often reach the age of a hundred. The same cuckoo was recognized by its peculiar note in the same forest for thirty-two consecutive years. Birds of prey becon.e much older, for they outlive more than one generation of men. A white-headed vulture was kept in a zoölogical garden in Germany for one hundred

and eighteen years; and many examples of eagles and falcons reaching an age of over a hundred years have been recorded. Humboldt mentions a parrot from the Orinoco, of which the Indians told that none could understand it, for it spoke the language of an extinct race.

Now let us compare the length of life and reproductive powers of the partridge and an eagle, and see if there is any reason why one should live longer than the other. The partridge lives a little more than twenty years, and each year lays about twenty eggs. Hence a pair of partridges may produce about four hundred eggs in their lifetime. This is at the rate of two thousand in a hundred years. Yet, since the number of partridges in the forest does not increase, three hundred and ninety-eight of these eggs, or young, must be destroyed in twenty years; while but two survive to take the place of their parents. The eggs and young are destroyed by beasts and birds of prey. If these enemies increased very much in number, the partridge would become extinct, unless it laid more eggs.

It would appear, then, that the partridge lays just eggs enough to ensure the continuance of its race; and, this being accomplished, death removes it. Many species have doubtless become extinct through the insufficiency of their reproductive powers. The number of offspring which, under ordinary conditions, would have ensured perpetuation, has proved insufficient when their enemies increased or the environment became unfavorable. The supply must be equal to the demand.

Now for the eagle. The eagle is one of the most powerful of birds, and builds its nest on such inaccessible cliffs that eggs and young are comparatively safe from marauding animals. Many, however, are destroyed by late frosts and snows. To be on the safe side, let us fix the duration of life of the eagle as sixty years; and of this, ten years are spent in immaturity. Hence there are fifty years of its life during which it reproduces. If the eagle lays but two eggs a year, a pair of eagles would produce one hundred during their lifetime. In a hundred years two hundred eggs against the partridge's two thousand; therefore the partridge produces ten times as many young as the eagle, and it is safe to say that the partridge has ten times as many enemies. If the life of either were short-

ened, the race would die out unless the power of reproduction were increased, or the struggle for existence became less severe.

Many sea-birds, such as the petrel, auk, and gannet, lay but one, or at the most two eggs a year. Any one who visits a locality where these birds breed must be struck with the enormous number of eggs or young which are destroyed. The eggs are often laid on the bare rock on projecting ledges of a cliff, so that the slightest movement will precipitate them to the beach below. Every disturbance among the breeding birds is marked by a small avalanche of eggs or young, so that the beach below is strewed with broken eggs and mangled remains. If these birds were not long-lived, they would soon become extinct. Now all of these birds live much longer than mammals of a far larger size. The lion lives thirty-five years, the sheep fifteen, the fox fourteen, the squirrel or mouse about six. Most of these animals are much more fertile than the birds, and the young are much less exposed to dangers. The bird's egg is exposed from the time it is laid, while the young mammal is protected during its development.

Only the very largest of the mammals, such as the whale, the elephant, and possibly the rhinoceros, live as long as these birds. The elephant may live for a hundred or perhaps a hundred and fifty years, and reaches maturity when about thirty. A pair produce but a single calf about every ten years; hence, during their lifetime, a pair of elephants contribute but ten or a dozen young to the race.

Wallace shows that we are living now in a zoölogically impoverished world. Almost all of the largest and strongest forms have recently become extinct: in Europe, the great Irish elk, the sabre-toothed tiger, cave-lion, rhinoceros, hippopotamus, and elephant; in North America, equally large felines, horses, and tapirs larger than any now living, a llama as large as a camel, mastodons and elephants, besides a large number of huge megatherians; in South America, an even greater number of megatherians, huge armadillos, a mastodon, large horses and tapirs, large porcupines, two kinds of antelopes, numerous bears and felines, besides the sabre-toothed tiger.

Remains of all these are found in the recent deposits, and these animals lived till shortly before the northern continents were encased with the ice of the glacial epoch. It is possible that a change of climate, due to the growing cold from the encroaching ice-belt,

affected the flora. This would, of course, affect the food supply, and so tend to lessen the reproductive powers, and shorten the lives of the individuals. Lessened reproductive power and shortened lives of the individuals would surely result in the extinction of the race, and in this way the destruction of these forms may be accounted for. The starvation of the individual is therefore synonymous with the starvation of the race.

The above considerations seem to warrant the theory advanced by Weismann: *first*, that unicellular organisms may be potentially immortal; *second*, that death is an adaptation; and *third*, that the length of life and the reproductive powers of animals are correlated.

## *THE APPLICATION OF THE ALPHA-SULPHONIC ACID OF NAPHTHALENE*[1] *TO THE BATING AND PURING OF HIDES AND SKINS.*

By PETER S. BURNS, S.B., and CHARLES S. HULL.

Improvements in the arts during the last half century, and more especially as regards the manufacture of leather, are confined almost entirely to methods for decreasing the cost through the adaptation of machinery; and little progress has been effected in the chemical methods employed, either to apply the present agents with greater economy, or new agents that may introduce economy of material or betterment in the quality of the finished product.

To briefly summarize the process of tanning, it may be said that the softened hide or skin is immersed in a solution of slaked lime, or other alkali, for a period varying from three days to a week. It is then taken out, and the hair, which is loosened by the action of the alkali, is mechanically removed. The skin would now be ready for the tanning liquors, were it not for the presence of the lime, which the fibre and gelatine of the skin absorb, and which it is necessary to remove before the tanning of the skin may be attempted. The necessity of removing the lime arises from the fact that, with it, tannic acid forms an insoluble compound, dark in color on account of the coloring matter with which it is precipitated, and also because of the oxidation of the tannate of lime in the presence of the alkali of the hide. It is found that besides becoming dark in color when lime is present, the hide tans very slowly, and that when the process of tanning is complete, the leather so produced is brittle and tender. It is in the removal of the lime that one of the greatest losses of material in the present methods occur, through a loss of

[1] This alpha-sulphonic acid of naphthalene is sold for tanners' use under the name "Acrilene Antiseptic Bating and Puring Acid."

gelatine to the hide structure itself. The processes now in use for the removal of the lime are invariably accompanied by and dependent upon the action of bacteria, which subsist upon and consume the hide while it is subjected to their action. These methods consist in immersing the hide in an animal or vegetable putrescent or fermenting solution, and the agents usually employed are hen, pigeon, or dog manure, sugar, glucose, and bran. The action of these agents by the dissolution of the gelatine results in the depletion of the hide, and allows of the removal of the lime. This is effected principally by mechanical means, such as working and washing, and is rendered possible only through the action of the bacteria on the hide structure itself, which becomes wasted and relaxed. Our experiments show that the removal of the lime is assisted by the carbonic and phosphoric acids and their ammonium salts, which were found to be present in the putrescent solution, as well as by formic, acetic, propionic, lactic, butyric, or other similar acids incident to the fermentations which are commonly resorted to. The loss of gelatine incident to these methods was found by experiment to amount to, as a minimum, from two to three per cent. of the weight of the dry hide submitted to their action. This loss is nearly doubled in the tanned leather, owing to the fact that leather may be considered to contain one half its dry weight of tannic acid. Our experiments on this subject have been made with the object of procuring an antiseptic chemical agent that would remove the lime without the attendant action of bacteria, and consequently without loss of gelatine to the hide. It is evident that the best way of removing the alkali is by converting it into a soluble salt by the use of an acid; but the common mineral acids whose lime salts are soluble act upon the hide in a most unexpected way, causing it to swell and assume a transparent and gelatinous appearance, thus rendering the hide useless for making most kinds of leather. The acids produced by the fermentation of bran, sugar, and glucose, give similarly unfavorable results; from which fact we are led to the conclusion that, when hides are submitted to *fermenting* solutions of these same agents, the depletion is due to the action of the bacteria, and not to the direct action of the acetic and other acids simultaneously generated. The organic acids were widely investigated, and from among the long list alpha-naphthalene-sulphonic acid alone was found to combine with and remove the alkali of the hide without mechan-

ical aid, leaving the hide soft and white, and without entailing any loss of gelatine. Why the sulphonic acid of naphthalene should remove the lime without causing the swelling and gelatinous appearance produced by the other acids, of which, perhaps, citric acid produces the most marked effect, we are unable to say at present. The antiseptic properties of naphthalene-sulphonic acid, which are about the same as *a*-phenol-sulphonic acid, make it most desirable for the use to which it is proposed to put it, while the low cost of the materials from which it is manufactured should bring it within the tanner's reach. The application of naphthalene-sulphonic acid to the manufacture of leather on a larger scale than was possible at the laboratory was made at the works of one of the largest calf-skin tanners in New York State. Two lots of calf-skins were taken for the trial, alike in condition and character. Each lot numbered 150 skins, and each weighed 880 pounds in the hair. Each skin of each lot was then given a distinguishing mark, and after the treatment with lime and removal of the hair, one lot of 150 skins was subjected to the hen-manure drench and the other lot to a three per cent. solution of the sulphonic acid of naphthalene. Both lots were then mixed and tanned in the same vats for the purpose of securing equal conditions. When the tanning was completed the skins were sorted into their original lots and weighed. It was found that the skins subjected to the hen-manure solution made 255 pounds of dry leather, which, when stuffed, weighed 395 pounds; and that the skins treated with the naphthalene-sulphonic acid made 266½ pounds of dry leather and 413 pounds of stuffed leather; both lots having been stuffed in the same operation — a net gain in finished weight of $4\frac{55}{100}$ per cent. It was also noted that the hen manure skins were very apparently lighter in the flanks and shoulders than those bated with the sulphonic acid. The safety and certainty with which this operation may be repeated by the most ignorant of workmen, thereby insuring equality in the value of the finished product, give it a great advantage over the present agents, which, aside from being very nasty and offensive, even to workmen familiar with their stench, are continually accompanied, especially in summer, by danger to the stock, even in the hands of the most experienced workmen.

LABORATORY OF THE INSTITUTE OF TECHNOLOGY,
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## *A DELICATE TEST FOR ALUM IN POTABLE WATER.*

By ELLEN H. RICHARDS.

In 1878–79, while making examinations of some food materials for the State Board of Health of Massachusetts, it was necessary to test for alum in bread, and also in baking powders, in the presence of sodium carbonate. The method which was found to be uniformly successful is given on page 161 of "Food Materials and their Adulterations" (Estes & Lauriat, Boston, 1886).

When alum came into use in various methods of purifying water on a large scale, it became important to find a test for it of as great delicacy as that for ammonia; for by the usual methods chemists had often reported no alum in these filtered waters.

Mr. George L. Heath, Assistant in Sanitary Chemistry in 1888–1890, successfully modified the logwood test for alum referred to above, so that it can be applied to potable waters.

On the addition of alum to natural waters, there is a precipitation of alumina in proportion to the amount of carbonates or bicarbonates present in the water. It is, of course, only the alum in excess of the amount decomposed that is to be tested for. The precipitation of the alumina is a gradual process, and a water that will give the test for alum immediately after filtering may give none after twenty-four hours, since the alum may have been all decomposed in the mean time. It is not unfrequently noted that the effluents from filters using alum which are originally clear, become cloudy on standing, in consequence of the separation of aluminum hydrate.

On the addition of alum to brown surface waters there is also a precipitation of alumina by the coloring matters, tannin, or other substances, and in this case also only the excess of alum is to be tested for. For instance, a sample of the Cochituate supply, of moderately deep color, to which twenty-five milligrams of alum to the

liter had been added, when filtered gave no reaction for alum, even when 2.5 liters were concentrated for the test. An addition of thirty milligrams to the liter could be detected without difficulty.

The method is as follows: To 25 cc. of the water to be tested (concentrated from one liter or more, if necessary) is added a few drops of freshly prepared logwood decoction; any alkali is neutralized and the color is brightened by the addition of two or three drops of acetic acid. By comparison with standard solutions, the amount of alum present may be determined. One part of alum in 1,000,000 of water can be detected with certainty. In cases of greater dilution, concentration of several liters may be necessary to obtain a decisive test. The logwood chips yield the right color only after having been treated with boiling water two or three times, and rejecting the successive decoctions. The first portion gives a yellow color, the third or fourth usually a deep red.

# *NOTES ON THE ACTION OF HYDROBROMIC AND HYDRIODIC ACIDS ON TIGLIC AND ANGELIC ACIDS.*[1]

By HENRY P. TALBOT, Ph.D.

In his article on the action of hydrobromic acid and of bromine upon tiglic and angelic acids, published in 1879, Pagenstecher[2] states that the additionproducts thus obtained from the angelic acid were identical with those yielded by the tiglic acid under the same conditions. This he proves in the case of the hydrobromic acid by showing the identity of the pseudobutylenes produced by treating these additionproducts with sodium carbonate.

In direct contradiction of this statement, Pückert[3] asserts that he obtained a dibromangelic acid which differed in its physical properties and in its decomposition products from the dibromtiglic acid prepared under the same conditions. Pückert characterizes the two new acids as geometric isomers, and shows the relation of both the dibrom-additionproducts, and of the brompseudobutylenes derived from them, to the geometrically isomeric acids which formed the starting point.[4]

The results of Pückert's investigation led Wislicenus[5] to express the opinion that the hydrobrom-additionproducts, which Pagenstecher regarded as identical, would prove to be geometric isomers, or that such isomers could be isolated.

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[1] A part of an Inaugural Dissertation entitled "Ueber das Verhalten der Tiglinsäure und der Angelicasäure gegen Bromwasserstoff und Jodwasserstoff," presented to the Faculty of the Leipzig University, Leipzig, 1890.

[2] Liebig's Annalen, 195, 108. [3] Liebig's Annalen, 250, 243.

[4] In a recent number of Liebig's Annalen der Chemie (259, 1) Fittig re-affirms the accuracy of Pagenstecher's work. Accordingly the question of the existence of a dibromangelic acid must be considered as still open.

[5] Liebig's Annalen, 250, 254.

Some years before Pückert's publication, Schmidt[1] had studied the action of hydriodic acid upon both tiglic and angelic acid, and states that he obtained a product from the angelic acid which differed essentially in its melting point from that prepared from the tiglic acid under similar conditions. Schmidt did not, however, succeed in preparing a pure product which he could characterize as iodohydroangelic acid, although he rendered the existence of such a compound very probable. He states that both the iodohydrotiglic acid and the product from the angelic acid yield the same methyl-ethyl-acetic acid upon reduction. Fittig[2] asserts that both additionproducts give the same pseudobutylene on treatment with sodium carbonate. He prepared his product in the same way as Schmidt, and does not state that he was successful in purifying the iodohydroangelic acid.

The recent discovery and identification by Mellikoff and Petrenko-Kritschenko[3] of four isomeric chloroxyvalerianic acids resulting from the action of hypochlorous acid upon the two organic acids in question, and exactly corresponding to the requirements of the theory of Le Bel and van't Hoff, made it appear still more probable that a review of Pagenstecher's and Schmidt's work would lead to the isolation of isomeric bromhydro- and iodohydro-additionproducts, and throw additional light upon the constitution of the tiglic and angelic acids themselves.

Such was the object of the present investigation, which was carried on at Leipzig, under the direction and at the request of Professor Wislicenus, to whom the writer is under great obligation for kind assistance and suggestion.

The tiglic and angelic acids, which were required as a starting point, were prepared as follows:

The angelic acid was obtained from the oil of the camomile (*Anthemis nobilis*), known in German trade as *Römisch Kamillenöl.* The oil was saponified in portions of 500 grms. each, by mixing with a solution 250 grms. of caustic potash in 125 cc. of water. The saponification was accomplished chiefly by vigorous shaking for a half-hour without the application of heat, beyond 5 – 10 minutes upon the steam bath at the close, to complete the reaction. A longer heating lessens the yield of angelic acid. After the removal of the alcohols and acidification with hydrochloric acid, the greater portion

[1] Liebig's Annalen, **208**, 253. Berichte der deutschen chemischen Gesellschaft, **12**, 255.

[2] Liebig's Annalen, **216**, 261. [3] Liebig's Annalen, **257**, 116.

of the organic acids separated as an oily layer. These were removed by a separating funnel, and the remainder extracted with ether. The acids were then subjected to fractional distillation, and after each fractionation the distillates were exposed to a temperature of 0°– 5° C. The angelic acid separated from the portions distilling between 181°– 184°, 184°– 187°, 187°– 190°. From the portions distilling above 190°, tiglic acid separated. The fractionation and cooling were repeated until the yield of angelic acid was so small as to make it useless to continue. The angelic acid was thoroughly pressed and twice recrystallized from distilled water.

The yield was 11% of the weight of oil used. The thoroughly dry acid melted sharply at 45° C.

The tiglic acid required was partially prepared by the reduction of methyl-acetacetic ether (Rohrbeck,[1] Pückert[2]), but the greater portion was obtained from the *Römisch Kamillenöl*, after the repeated fractionations. The fractions above 190° gradually increase in volume, and from these tiglic acid crystallizes readily. Moreover, the mixture of acids from which the angelic acid will no longer crystallize was heated for twenty hours or more to the boiling point, and from this mixture (in which the angelic acid gradually changes to tiglic acid), considerable quantities of the latter acid were obtainable. The tiglic acid was recrystallized from distilled water, and after thorough drying melted sharply at 65° C.

Both the tiglic and the angelic acids were thoroughly dried before they were subjected to the action of either hydrobromic or hydriodic acid.

A long series of carefully conducted experiments, carried on under varying conditions, upon the action of hydrobromic acid upon angelic acid, yielded but one result, viz.: the additionproduct, after purification, could not be distinguished in any of its physical properties from that obtained from tiglic acid under the same conditions, although its purification was always attended by greater difficulty owing to the presence of a minute quantity of some other substance.

This, in itself, confirms the results obtained by Pagenstecher. At the same time, the fact which will be spoken of later, that different products do result from the action of hydriodic acid upon these same organic acids (as well as the work of Mellikoff and Petrenko-Kritschenko already referred to), seems to admit of the hope that a bromhydroangelic acid may yet be isolated.

[1] Liebig's Annalen, **188**, 235. [2] *Ibid.*, **250**, 243.

The experiments with hydrobromic acid may be briefly outlined as follows:

Hydrobromic acid was allowed to act upon the tiglic and angelic acids in aqueous solution, and also in solution in ether, chloroform, and low-boiling petroleum products (petroleum ether). The addition of the hydrobromic acid took place very slowly, except in ethereal solution. In the latter case the addition was nearly complete at the end of an hour, whereas it required many days in the other solvents. Experiments also indicated that even in this short time the contact with hydrobromic acid had caused the angelic acid to change into a derivative of tiglic acid.

The action of the hydrobromic acid in the ethereal solution yielded unexpected results, in so far as the product, in all cases in which the acids remained in contact with the ether for more than an hour, was an ethyl ester of bromhydrotiglic acid instead of the free acid. The formation of the ester was the result of a secondary reaction between the hydrobromic acid and the ether, in which ethyl alcohol and ethyl bromide were formed. The alcohol, in the presence of the hydrobromic acid, formed an ester with the bromhydrotiglic acid. Tiglic acid was the only acid which could be obtained from these esters by saponification.

The additionproduct obtained from the angelic acid when treated in aqueous solution, or in petroleum ether, agreed in melting point, solubility in petroleum ether, behavior when melted under water and when rubbed together with tiglic or angelic acids, with the bromhydrotiglic acid.

The same was true of the products obtained when chloroform was the solvent, with one exception. In this medium the addition of the hydrogen and bromine took place with great slowness. In one instance, after standing with hydrobromic acid for forty-eight days, a small quantity of an oily substance was obtained from angelic acid which was soluble in sodium carbonate solution, and contained 44.04% bromine (theoretical for $C_5H_9O_2Br$., 44.19%). This body may correspond in character with that observed by Fittig,[1] which formed with the dibromtiglic acid on the addition of bromine to angelic acid, and which he regards as a possible dibromangelic acid. In this series of experiments the solutions were allowed to stand in a cool place and in diffused light; never in *direct sunlight.*

[1] Liebig's Annalen, **259**, 26.

The action of hydriodic acid upon the tiglic and angelic acids was first tried in aqueous solution according to the directions given by Schmidt.[1] A quantity of aqueous hydriodic acid was completely saturated with the gas at 0°. Of this concentrated acid 80 grms. were taken for each 10 grms. of tiglic or angelic acid. The solution of these acids followed quickly, and after standing eighteen hours away from the light, the solution containing the tiglic acid had become a semi-solid mass, while a layer of oil, which crystallized on shaking, had separated from the solution of the angelic acid. The crystals were collected on a filter of glass-wool, washed, pressed and dried over soda-lime.

The iodohydrotiglic acid, after a single recrystallization from petroleum ether, melted sharply at 86.5°–87°, a half-degree higher than the melting point recorded by Schmidt.

Analysis:

0.3675 grms. substance yielded 0.3780 grms. Ag I

| Calculated for $C_5H_9O_2I$ | Found. |
|---|---|
| 55.70% I | 55.56% I |

The yield amounted to 87% of the theoretical quantity. The crystals from the angelic acid after one recrystallization melted at 44°–50°. After repeated recrystallization they melted from 46° to 70°, chiefly between 46° and 50°. Schmidt records a similar behavior of his product from angelic acid.

It was only possible to obtain a small quantity of crystals melting between 84° and 86.5°, which were undoubtedly iodohydrotiglic acid. It was evident from its behavior that this product was not a single substance, but a mixture. To determine whether the mixture was one of unchanged acid with the iodohydro-acid, a determination of the iodine was made which resulted as follows:

I. 0.2080 grms. substance gave 0.2149 grms. Ag I
II. 0.1948 " " " 0.2024 " Ag I

| Calculated for $C_5H_9O_2I$ | Found. |
|---|---|
| 55.70% I | I. 55.81 |
| | II. 56.10 |

From these percentages it appears that the mixture is composed of two or more substances corresponding to the symbol of iodohydro-angelic acid. This is a direct confirmation of Schmidt's results.

Wislicenus has established the fact that the presence of moisture

[1] Liebig's Annalen, **208**, 254.

frequently leads to the formation of abnormal products in reactions intended to produce geometric isomers, especially in the case of the less stable of these isomeric compounds. He has, moreover, proved by a series of experiments that the presence of direct sunlight also leads to the formation of abnormal products. Fittig[1] publishes some striking results bearing on this point.

In the second series of experiments, an attempt was made to exclude both light and moisture. The exclusion of the moisture was attained by the use of chloroform as a solvent. Chloroform, free from alcohol, was saturated with dry hydriodic acid gas, and the amount of the hydriodic acid in each cubic centimeter determined by titration. The quantity of the organic acids was so chosen that a considerable excess of the hydriodic acid was present. The solution stood, away from the light, and at 15° C., for seven days. The chloroform and the excess of hydriodic acid were then removed by evaporation in a current of dry air, the solution being protected from the light during the evaporation.

The crystals remaining from the solution of the tiglic acid proved to be identical with those prepared from hydriodic acid in aqueous solution. The yield was 95% of the theoretical quantity.

The yield of crystals from the angelic acid amounted to 98% of the theoretical quantity. Their purification presented greater difficulty than that of the iodohydrotiglic acid, owing to their ready solubility in all organic solvents.

By solution in slightly warm petroleum ether and repeated partial evaporation of the solvent in dry air, four crystallizations were obtained. The crystals of the first portion melted from 58.5°–60.5°; of the second, at 56°–58°; of the third, at 51°–56°; and of the residue after the complete removal of the solvent at 42°–50°. The latter portion was in all respects similar to the mixture obtained from the hydriodic acid in aqueous solution, and resisted all attempts to separate it into its constituents. An analysis showed that it contained 55.94% I (theoretical for $C_5H_9O_2I$, 55.70%).

From the crystals melting between 51° and 60.5° a considerable quantity of a substance melting sharply between 59.5° and 60.5° was obtainable by recrystallization. This substance, in distinction from the mixture, showed all the properties of a uniform body.

[1] Liebig's Annalen, **259**, 18.

Analyses:

I. 0.1427 grms. substance yielded 0.1473 grms. Ag I
II. 0.2923 " " " 0.3015 " Ag I

| Calculated for | Found. |
|---|---|
| $C_5H_9O_2$ I | I. 55.77% I |
| 55.70% I | II. 55.72% I |

These analyses indicated that the substance in hand was an iodohydroangelic acid.

Although the recrystallization was conducted as far as possible out of the light, it was evident that the iodohydroangelic acid gradually changed into iodohydrotiglic acid, as the pure crystals, on warming for a little time with petroleum ether, would lose their sharp melting point without loss of iodine. When both moisture and light were carefully excluded during the whole process of preparation, the yield of pure iodohydroangelic acid was 70% of the total product. The yield was but 54% when light was not excluded. Both the iodohydrotiglic and the iodohydroangelic acids form well-defined crystals.[1]

As an additional means of comparison of these two acids, the solubility of each in petroleum ether and in water was determined.

---

[1] Specimens of the crystals of each of these acids were sent to Dr. A. Fock in Berlin, who very kindly examined them crystallographically, and reports as follows:

IODOHYDROTIGLIC ACID.

Crystals belong to the monoclinic system.

$$a : b : c = 1.7049 : 1 : 0.8732 \qquad \beta = 82° 21'$$

Forms observed:

$$a = (100) \infty \breve{P} \infty \qquad c = (001) 0P \qquad s = (101) -\breve{P} \infty \qquad m = (110) \infty P$$
$$o = (\bar{1}21) +2\breve{P}2 \qquad p = (121) -2\breve{P}2$$

The crystals are tabular in the direction of the orthodiagonal section $a$. The hemidome $s$ and the hemipyramids $p$ and $o$ occur but rarely. The cleavage, parallel to the orthodiagonal section, is perfect. The position of the optical axes cannot be detected either in the base or in the orthodiagonal section.

IODOHYDROANGELIC ACID.

The crystals belong to the monoclinic system.

$$a : b : c = 0.2741 : 1 : 0.2145$$
$$\beta = 57° 9'$$

Forms observed:

$$b = (010) \infty \breve{P} \infty \qquad m = (110) \infty P, \; q = (011) \breve{P} \infty$$

The crystals are mostly prismatic in the direction of the vertical axis; a few individuals are tabular in the direction of the plane of symmetry. An optical examination shows that the crystals are almost without exception twins, the twin plane being the orthodiagonal section, so that a purely geometric examination would easily lead one to assert that the crystals belonged to the rhombic system.

The cleavage is perfect in the direction of the clino-diagonal section.

The finely pulverized acid was covered with a quantity of the solvent insufficient for complete solution and allowed to stand for four or five hours at a definite temperature, with occasional shaking. The solution was then decanted, weighed, the petroleum ether removed by evaporation in a current of dry air, and the residual acid weighed.

The results are tabulated below:

IODOHYDROTIGLIC ACID.

| Temperature. | Weight of solvent. | Weight of dissolved acid. | Parts acid dissolved per 100 parts solvent. |
|---|---|---|---|
| 20.5° C. | 18.8250 | 0.5460 | 2.90 |
| 22° | 18.6260 | 0.5750 | 3.09 |
| 24° | 18.0373 | 0.7310 | 4.05 |
| IODOHYDROANGELIC ACID. | | | |
| 20.5° | 7.6163 | 1.2865 | 16.8 |
| 22° | 11.8910 | 2.5095 | 21.1 |
| 24° | 12.9013 | 2.8950 | 22.4 |

The difference in solubility is most striking.

The solubility in water was determined by titrating the decanted solution, after weighing, with caustic potash, using litmus as an indicator. The first appearance of a decided blue was taken as the end point. This corresponds approximately to one molecule of the alkali to one of the acid, but the results are probably not accurate within about three or four per cent.

IODOHYDROTIGLIC ACID.

| Temperature. | Weight of solvent. | Weight of dissolved acid. | Parts acid dissolved per 100 parts solvent. |
|---|---|---|---|
| 20° C. | 47.3587 | 0.3053 | 0.64 |
| 20.5° C. | 41.5344 | 0.2736 | 0.65 |
| IODOHYDROANGELIC ACID. | | | |
| 20° C. | 43.2717 | 0.6440 | 1.49 |
| 20.5° C. | 38.5124 | 0.5996 | 1.55 |

Here, again, the iodohydroangelic acid shows a decidedly greater solubility.

Finally, the behavior of the two new acids when brought into contact with the original acids was examined, and it was found that when iodohydrotiglic acid was intimately mixed with tiglic acid by rubbing together in an agate mortar, in the proportion of one molecule of each, a mixture results which melts between 44° and 60°. Iodohydroangelic acid and tiglic acid, molecule for molecule, yield a mixture melting between 28° and 32°.

One molecule of iodohydrotiglic acid with one molecule of angelic acid affords a mixture melting between 28° and 62°, while one molecule of iodohydroangelic acid with one molecule angelic acid immediately forms an *oil.*

After the comparison of the properties of these two addition-products, it is not to be doubted that they are distinctly different bodies, differing in melting point, crystal form, and solubility. Experiments have been made upon the decomposition products which these iodohydro-acids yield, which, if confirmed, seem to indicate that the pseudobutylenes produced by the action of sodium carbonate upon these acids are not identical, as Fittig asserts, but can be shown to be geometric isomers whose derivation from the original tiglic and angelic acids can be shown. Since, however, the accuracy of the results obtained by Hölz[1] in his work upon the isomeric brompseudobutylenes, with which the bromine compounds of the pseudobutylenes obtained from these acids were compared, has been questioned by Faworsky and Debout,[2] a confirmation of the results of these experiments is necessary, and the question of the identity of the decomposition products from the iodohydrotiglic and the iodohydroangelic acids must remain open for the present.

[1] Liebig's Annalen, 250, 224. [2] Journal für praktische Chemie, 42, 149.

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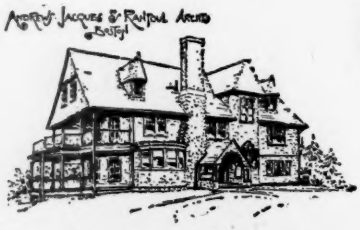

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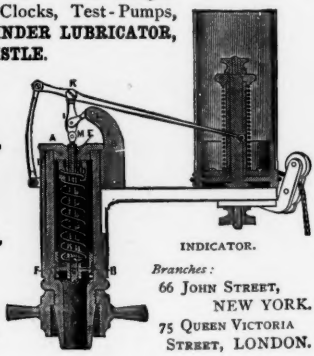

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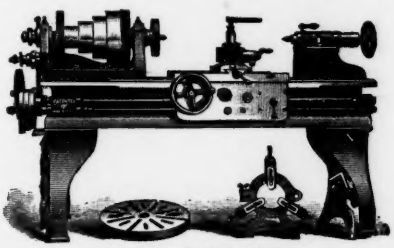

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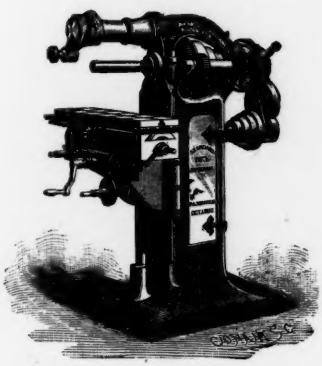

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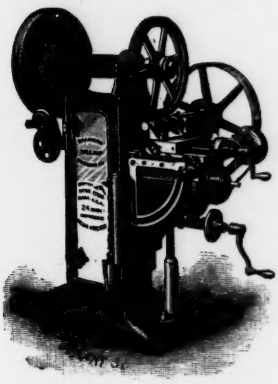

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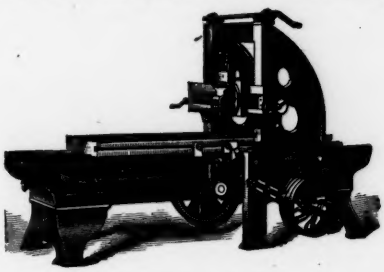

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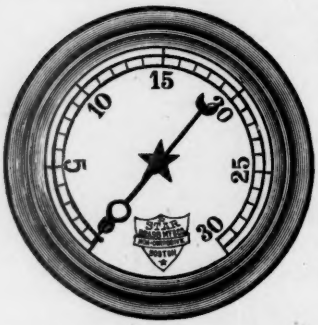


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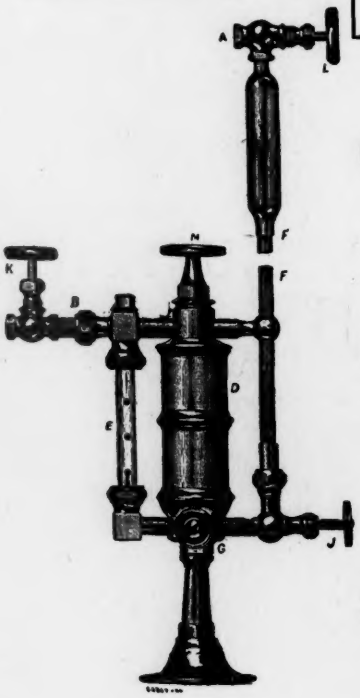


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